Comparative Winterhardiness of Cultivated and Native Alaskan Grasses, and Forage Yield and Quality as Influenced by Harvest Schedules and Frequencies, and Rates of Applied Nitrogen

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Table of Contents

List of Tables and Figures

SUMMARY

Objectives of this investigation were to compare certain traditional forage grasses with several native Alaskan grass species for forage yield, forage quality as measured by percent crude protein and digestibility (*in vitro* dry-matter disappearance or percent IVDMD), and comparative winterhardiness in three separate experiments. Management variables included different harvest frequencies (2, 3, and 4 times per year), and five different rates of applied nitrogen (N). Experiments were conducted at the University of Alaska's Matanuska Research Farm (61.6°N) near Palmer in southcentral Alaska.

All species were tall-growing, cool-season perennials. Traditional forage grasses included 'Polar' hybrid bromegrass (predominantly *Bromus inermis* x *B. pumpellianus*), 'Engmo' timothy (*Phleum pratense*), 'Garrison' creeping foxtail (*Alopecurus arundinaceus*), and a non-cultivar, commercial meadow foxtail (*A. pratensis*). Native Alaskan species were Siberian wildrye (*Elymus sibiricus*), slender wheatgrass (*Agropyron trachycaulum*), arctic wheatgrass (*A. sericeum*), bluejoint (*Calamagrostis canadensis*), and polargrass (*Arctagrostis arundinacea*).

• The least winterhardy of the nine grasses were Engmo timothy and meadow foxtail (Exps. I and II). The other two cultivated grasses, Garrison creeping foxtail and Polar bromegrass, were much more winterhardy; however, even they sustained considerable injury during the severe winter of 1970-71, but both recovered well during the 1971 growing season (Exp. II). In contrast, the native grasses showed no evidence of winter injury in any of the experiments.

• Total annual forage dry-matter yields of all grasses generally were highest with two cuttings per year and became progressively less as the number of cuttings per year increased (Exps. I and II).

• When six grasses were cut 2, 3, and 4 times per year, meadow foxtail and native slender and arctic wheatgrasses and Siberian wildrye tended to be more injured by 3 cuttings per year than were Polar bromegrass and Engmo timothy. All grasses showed evidence of tolerating two cuts per year better than three or four except Engmo which tended to produce better in the third year where it had been harvested most frequently (Exps. I and II).

• With two cuttings per year, total annual forage yields were highest with the latest of three first-cutting dates (7 July vs. 23 June or 8 June) (Exp. II).

• Engmo timothy invariably was significantly higher in percent IVDMD than six other grasses in the final (23 Sep.) harvest under all of five different harvest schedules. Moreover, Engmo forage yields in the 23 September harvest always were equivalent to, and sometimes significantly surpassed, the other highest yielders (Exp. II).

• The native grasses tended to be lower in forage yield in the final (23 Sep.) harvest than the traditional forage grasses, regardless of previous harvest schedule (Exp. II). Increased rates of N application up to 216 lb/A (1/3 at midseason), however, tended to increase second-cut yields of all grasses over yields at lower N rates (Exp. III).

• With three or four cuttings per year, digestibility (percent IVDMD) generally remained high with all grasses, and higher than in the herbage in either harvest with two cuttings per year (the only exception with two cuttings was high percent IVDMD in the very early 8 June first cutting) (Exp. II).

• With two cuttings per year, digestibility in the second cutting increased with shorter growth periods before the second harvest (= later first cuttings) (Exp. II).

• Bluejoint was often significantly lower in digestibility than the other grasses (Exps. II and III); arctic wheatgrass also tended to be lower in digestibility than other grasses in the second of two cuttings (Exp. III).

• At the lowest rate of N application, traditional forage grasses (bromegrass and creeping foxtail) and native Siberian wildrye were significantly higher in digestibility in the first (29 June) of two cuttings than the other native Alaskan grasses (bluejoint, polargrass, slender and arctic wheatgrasses). However, at higher rates of N (over 100 lb/A in spring), the latter four native grasses increased significantly in digestibility to equal the other grasses while, in contrast, the first-mentioned three grasses changed little (Exp. III).

• With two cuttings per year and the first cutting prior to July, digestibility in the first harvest generally surpassed that in the second cutting (Exps. II and III), especially with higher rates of applied N (Exp. III). However, with a late first cutting (7 July), digestibility in the second cutting (23 Sep.) tended to be higher than in the first cutting with all grasses except the wheatgrasses (Exp. II).

• Grasses differed considerably in yields of digestible dry matter; mean range in yield between highest and lowest yielder at five N rates was 0.71 T/A (Exp. III).

• Yields of digestible dry matter of all grasses were increased with increasing rates of applied N up to 216 lb/A. The increases generally were due to the combined effect of higher forage yields and enhanced digestibility with increasing rates of N (Exp. III).

• Native polargrass was generally highest in yield of digestible dry matter at all N rates; at the highest N rates bluejoint was second to polargrass and surpassed other grasses (Exp. III).

• Percent crude protein in grass herbage generally increased with increasing rates of applied N, more so in

the first cutting than in the second; this may be at least in part a result of 2/3 of N being applied in spring and 1/3 at mid-season (Exp. III).

• With two cuttings per year on 29 June and 18 September, percent crude protein generally was higher in first-cutting forage than in the second harvest; those differences were greatest in the native grasses at the highest rates of applied N (Exp. III).

• Relatively high rates of applied N (with adequacy of other major nutrients) generally stimulated increases in dry-matter production, percent IVDMD, and percent crude protein of all grasses; those responses tended to be of greater magnitude in first-cutting forage than in the second cutting (Exp. III).

• Percent dry matter in first-cutting herbage of all grasses decreased with increasing rates of N application, with the most rapid decline between 36 and 108 lb of N/A (spring applied); decline in percent dry matter at higher rates (144 and 180 lb/A) was less pronounced in all grasses except Garrison foxtail. Polargrass herbage was much lower in percent dry matter than all other grasses.

• Except for Engmo timothy which winterkilled totally, the seven other grasses compared in Exps. II and III persisted well, continuing to produce good yields of forage in their sixth year of growth.

• The reputation of native bluejoint of being intolerant of annual utilization is again shown to be due to conditions inherent in native stands of this grass and not a characteristic of the grass itself. When seeded on mineral soil (as with cultivated grasses) and grown divorced from the accumulated, undecomposed organic debris present in native stands, bluejoint responded well to fertilizers and tolerated regular harvesting well, producing forage yields equivalent to cultivated forage grasses (Exps. II, III, and follow-up harvests).

• The very markedly improved digestibility of bluejoint when supplied with about 200 lb N per acre may represent a key to not only producing high forage yields but, perhaps more importantly, enhancing the nutritional value of this species that grows native in vast acreages of strongly acidic soils but has been burdened with a reputation of poor forage quality. The added cost of fertilizer for that improved nutritional status could circumvent expensive liming that would be needed in those areas to grow other forage species (Exp. III).

• Only very minor residual effects of the different N rates were apparent in first-cutting forage yields of four of the seven grasses in the year after the several rates had been applied in Exp. III (a uniform application of fertilizer was applied to all plots that year). No residual effects were apparent in second-cut forage yields that year, or in first-cut yields the following year.

INTRODUCTION

Livestock require a continuous supply of high-quality forage to meet roughage requirements. Although some forage requirements in Alaska are supplied by annual species, most are produced from perennial grasses (Brown *et al.* 1993). Those grasses are utilized as pasturage, for green-chop feeding, or as preserved forms including baled or loose hay, haylage, and silage.

Desirable Forage Grass Characteristics

To adequately meet those forage needs, the grasses used should produce high yields of palatable, nutritious forage. Other desirable agronomic attributes include winterhardiness, early spring growth, rapid recovery after harvest, upright growth easily recovered by harvest equipment, lodging and disease resistance, and good productivity throughout the growing season.

"Cultivated" and "Native" Grasses

All grass species were "wild" or "native" in ancient times. However, over many centuries, with the advent and growth of agriculture, some were selected for culture for livestock utilization and have become our present so-called "cultivated" forage and pasture species. This has resulted in more extensive dispersal of many of those species throughout the world by artificial activities than occurred in nature.

Perhaps partly because agriculture was practiced earlier on the Eurasian continent, and partly also because that continent is recognized as the area of origin of most of the world's grass and legume species, most of the cultivated forage grasses currently in use in North American agriculture have been introduced into this continent from Europe and Asia (Hanson 1972).

Most of the "cultivated" forage grasses used on rotational croplands in Alaska originated from lower latitudes in Eurasia and have been grown in more southern areas in the U.S. and Canada before having been brought north into this state during recent decades. They therefore do not possess ideal adaptation to Alaska's far-northern climatological patterns. Consequently, forages introduced from more southern latitudes can be marginal to poor in winterhardiness when grown here, depending on the severity of individual winters (Klebesadel 1969b, 1991, 1992, 1994; Klebesadel and Dofing 1991; Klebesadel and Helm 1986, 1992a, 1992b).

In contrast, native Alaskan grasses, by virtue of long residence in this area, possess ideal adaptation to our north-latitude conditions. They do not, however, have a long history of use as forage crops, nor have they been subjected through a long history of utilization to natural or artificial selection for genotypes that ideally fulfill various avenues within which forages are utilized.

The present study compares four introduced, cultivated forage grasses with several tall-growing species native to Alaska for various agronomic characteristics and responses to management variables. Brief comments on each species follow.

Introduced Forage Grasses

SMOOTH BROMEGRASS (*Bromus inermis*) was noted early to be among the most promising of introduced perennial grasses evaluated for use in Alaska (Aamodt and Savage 1949; Alberts 1933; Irwin 1945). It is grown extensively throughout the northern U.S. and Canada (Carlson and Newell 1985; Smith *et al.* 1986) and has become the most extensively grown forage grass on rotational croplands in Alaska.

The northernmost-adapted strains of smooth bromegrass generally are winterhardy in Alaska; however, they can sustain severe injury if mismanaged (Klebesadel 1993a, 1994) or during occasional winters that impose unusually harsh winter stresses on overwintering crops (Wilton *et al.* 1966).

Polar bromegrass, a cultivar developed in Alaska (Hodgson *et al.* 1971; Wilton *et al.* 1966), is more winterhardy than cultivars of smooth bromegrass introduced from elsewhere (Klebesadel 1994; Klebesadel and Helm 1992a; Wilton *et al.* 1966); the superior winterhardiness of Polar is attributable to incorporation of subarctic-adapted pumpelly bromegrass germplasm into its genetic makeup.

TIMOTHY (*Phleum pratense*) is native to Eurasia and is a valued forage grass in cool, humid climates from temperate to subarctic regions (Childers and Hanson 1985; Smith *et al.* 1986).

A great many named varieties or cultivars have been developed, both in Europe and in North America. Although North American cultivars and strains are nonhardy to marginally winterhardy in Alaska, cultivars such as Engmo, adapted above the Arctic Circle in Norway, are the preferred choice for best winter survival in Alaska (Klebesadel and Helm 1986; Mitchell 1989).

MEADOW FOXTAIL (*Alopecurus pratensis*), sometimes called Scotch timothy, is grown in Europe to a considerable extent as a hay grass on rather wet lands (Schoth 1947). It was introduced into North America from Eurasia but is not widely used in the U.S. except in special situations such as wetland pastures, particularly in the Pacific Northwest states (Hanson 1972; Lewis 1958).

Reports of early evaluations of meadow foxtail in Alaska were generally favorable (Aamodt and Savage 1949; Irwin 1945). Meadow foxtail is more tolerant of moderate soil acidity than smooth bromegrass; therefore, because Alaska has a considerable extent of soils that are moderately acidic, and areas that generally are high in moisture content, meadow foxtail was included in part of this study. Currently there are no named cultivars of meadow foxtail (Hanson 1972).

CREEPING FOXTAIL (*A. arundinaceus*) is closely related to meadow foxtail but spreads much more vigorously by growth of underground rhizomes. Like meadow foxtail, creeping foxtail also was introduced into North America from Eurasia, apparently about 1902 (Stroh *et al.* 1978).

The natural range of creeping foxtail covers a vast area in Europe and Asia from the Mediterranean region to north of the Arctic Circle (Stroh *et al.* 1978). The cultivar

Garrison, included in part of this study, was selected from naturalized stands in North Dakota that had originated from introductions from the Ukraine area.

Alaska's Native Grasses

The wealth of native grasses in Alaska was recognized early by explorers, visiting botanists, agronomists and others (Aamodt and Savage 1949; Bennett 1918; Lamson-Scribner and Merrill 1910; Piper 1905; Vasey 1893). In later reports, taxonomists have catalogued the considerable variety and distribution of species (Hulten 1968; Welsh 1974).

Some ranchers and farmers have harvested mixed native stands dominated by bluejoint (*Calamagrostis canadensis*) for forage. Other tall-growing native grasses that have exhibited excellent winterhardiness and potential for use as forage crops in preliminary field-nursery evaluations include polargrass (*Arctagrostis arundinacea*), Siberian wildrye (*Elymus sibiricus*), slender wheatgrass (*Agropyron trachycaulum*), and arctic wheatgrass (*A. sericeum*).

BLUEJOINT is perhaps the most widespread native grass in this state (Aamodt and Savage 1949; Hulten 1968; Welsh 1974). This fine-stemmed perennial usually grows in mixed associations with other grasses and forbs (Mitchell and Evans 1966) but, due to its tall growth, it is often the most conspicuous, and frequently is the dominant component in vast areas of mixed vegetation.

Bluejoint has been utilized as pasture and as harvested forage in native stands on both the southcentral mainland and certain islands from the time of Russian agricultural activity in Alaska to the present (Aamodt and Savage 1949; Compton and Brundage 1971; Irwin 1945; Klebesadel and Laughlin 1964; Mitchell 1979). Due to its extensive native range elsewhere in North America, it is utilized also in Canada (Corns and Schraa 1962) and in the U.S. Midwest where it often is the major component of "wild hay" (Hitchcock 1951).

A unique characteristic of bluejoint is its ability to thrive in strongly acidic soils where most other forage grasses and legumes grow very poorly. The considerable extent of acidic soils in some agricultural areas of Alaska (e.g. Kenai Peninsula, Kodiak Island), and the significant expense of liming agents to ameliorate soil acidity in Alaska, focus greater attention on bluejoint for use in such areas.

Early reports of bluejoint forage quality as indicated by crude protein concentration noted a rapid decrease with advance of plant development during the growing season (Alberts 1933; Capen and LeClerc 1933; Irwin 1945). McKendrick *et al.* (1977) reported the rapid and considerable decline in digestibility with advancing maturity of bluejoint forage harvested periodically from an unfertilized native stand.

During recent decades, several investigations have sought to ascertain more clearly the potentials and limitations of bluejoint for forage use in Alaska, both in native stands and seeded on croplands (Klebesadel 1965; Klebesadel and Laughlin 1964; Laughlin 1969; Laughlin *et al.* 1984; Mitchell 1979, 1982, 1986, 1987; Mitchell *et al.* 1983).

Bluejoint seeds are much smaller than those of most other forage grasses and require specialized processing after harvest (Klebesadel *et al.* 1962). Their small size results in generally poor seedling vigor, thus requiring very shallow seeding and effective weed control during establishment.

POLARGRASS somewhat resembles bluejoint and both grasses often are found growing in association; however, polargrass generally is found where soils are more moist. Moreover, polargrass usually does not occur as extensively in vast continuous stands as does bluejoint. When well supplied with moisture, polargrass is very productive of forage (Klebesadel 1969a; Mitchell 1982, 1986, 1987). In view of its propensity for occupying sites well supplied with moisture in nature, it is not surprising that Lawrence and Ratzlaff (1985) reported that polargrass established poorly, was low-yielding, and failed to persist under semi-arid conditions in Saskatchewan.

As with bluejoint, polargrass seeds are extremely small and require specialized equipment and considerable care during seeding and stand establishment (Klebesadel 1969a).

Some comparisons of forage yield and quality have been reported for polargrass and other grasses (Klebesadel 1969a; Mitchell 1982, 1986, 1987); however, more information is needed on the potentials and limitations of polargrass and its response to management variables including various rates of fertilization.

SIBERIAN WILDRYE is an extremely winterhardy grass occurring in the wild in various areas of southcentral Alaska (Hulten 1968; Klebesadel 1969b, 1993b; Welsh 1974). Whether it is truly native or introduced from Asia (where it occurs more widely) during early Russian occupation of Alaska remains obscure, but for this report it is grouped with the native grasses.

Siberian wildrye produces high seed yields (Klebesadel and Helm 1992b); moreover, forage yield and quality comparisons with other grasses have been favorable (Klebesadel 1969b, 1993b). The presence of bristly, scabrous awns in the seed heads of this grass, however, probably would limit its palatability after seedhead emergence and could cause feeding problems if fed as dried hay.

SLENDER and ARCTIC WHEATGRASSES occur widely throughout Alaska (Hulten 1968; Welsh 1974), and represent two of the most promising of several native wheatgrasses potentially useful as forages or for non-cropland applications such as revegetation of disturbed sites for soil stabilization (Klebesadel 1991; Klebesadel and Helm 1992b; Mitchell 1982).

Slender wheatgrass is native from Alaska to western areas of the conterminous 48 states; however, cultivars of this species selected for use at more southern latitudes are inadequately winterhardy for dependable use in Alaska (Klebesadel 1991). Therefore, native Alaskan slender wheatgrass is preferred for use in this area due to its superior adaptation and winterhardiness, and native collections have performed well in some evaluations reported earlier (Klebesadel 1991; Mitchell 1982).

The native range of arctic wheatgrass is more restricted to northern latitudes than that of slender wheatgrass. Some uncertainty continues concerning whether this grass is identical to the rhizomatous Asiatic species classified as *Agropyron macrourum* (Hulten 1968; Welsh 1974). Mitchell (1982), using Alaska-collected seed in a separate study, referred to it as "macroura wheatgrass" (*A. macrourum*). However, the present report, with some reservations, retains the *A. sericeum* identification and the common name "arctic wheatgrass" (in recognition of its high-latitude, circumpolar range) and as reported elsewhere (Klebesadel 1973; Klebesadel and Helm 1992b), owing to a consistent absence of evidence of rhizomatous spreading in the material used.

Little is known of how these wheatgrasses would react to different harvest schedules and frequencies, or to different rates of fertilization.

Other Forage-Grass Evaluations in Alaska

Irwin (1945) summarized many early evaluations of grasses conducted in Alaska during the period 1898-1945 at seven widely separated experiment stations. Although a considerable number of grasses were tried, assessments of usefulness were for the most part very cursory, observation-type evaluations with little or no data to support general comments on performance. Moreover, essentially no record was provided of the origins of strains, information that might provide background on geographic or climatic adaptation of species and strains used in tests. Very rarely were native Alaskan grasses grown for evaluation in those early cropland trials.

Only recently have there been published reports of large-scale evaluations and comparisons in Alaska of introduced and native grasses, and cultivars developed in Alaska, under closely controlled experimental conditions with data reported on forage yields, quality factors, winterhardiness, and other agronomic characteristics (Klebesadel 1992, 1993b; Klebesadel and Dofing 1991; Klebesadel and Helm 1986, 1992b; Mitchell 1982, 1986, 1987).

This Study

Four traditional forage grasses were compared with five species native to Alaska. Grasses were compared for responses to management variables that included different frequencies and schedules of forage harvests and the effects of five different rates of nitrogen fertilization on yield and quality of forage. All experiments were conducted at the University of Alaska's Matanuska Research Farm (61.6°N) near Palmer in southcentral Alaska.

EXPERIMENTAL PROCEDURES

Three separate broadcast-seeded field-plot experiments (Exps. I, II, III) were conducted in Knik silt loam soil (Typic Cryochrept) with good surface drainage. All experimental sites were in field areas exposed to winter winds that often removed snow cover.

Preplant commercial fertilizer disked into plowed seedbeds for each planting supplied nitrogen (N), phosphorus (as P_2O_5), and potassium (as K_2O) at 32, 128, and 64 lb/A, respectively, for Exp. I, and at 36, 148, and 72 lb/A, respectively, in establishing grass stands that served for Exps. II and III. No companion crops were planted.

All grass strains were seeded in plots measuring 5 by 20 feet in Exp. I and 5 by 18 feet in Exps. II and III. Seed was covered shallowly by lightly stirring the soil surface with fork tines, and seedbeds were then firmed by drawing a corrugated-roller packer over the entire experimental area. Split-plot experimental designs were used with four replications. Harvest schedules were used as whole plots and grass strains as sub-plots. All references to statistical significance in this report are based on 95% confidence limits.

To remove border effects at each forage harvest, a strip 1.25 feet wide was clipped and removed from both ends of plots to be harvested. A swath 2.5 feet wide was then clipped and weighed from the centerline of each plot, leaving about a 2-inch stubble. Grass growth remaining on each plot, bordering the harvested swath, was also clipped and removed immediately. After occurrence of killing frost each autumn, each entire experimental area was clipped to a uniform 2-inch stubble to prevent uneven snow retention on plots over winter.

A small, bagged sample was taken from the herbage harvested from each plot, weighed immediately, then dried to constant weight at 140°F; percent dry matter in each sample was used to calculate oven-dry yields reported. Those samples were then ground finely and analyzed for crude protein (N x 6.25) by the Kjeldahl method. For determinations of percent *in vitro* dry-matter digestibility (IVDMD) in Exps. II and III, a second herbage sample was withdrawn from harvested material and dried at 90°F before being ground finely for laboratory procedures.

Experiment I (Six grasses harvested two, three, and four times per year): Six cool-season, tall-growing perennial grasses were planted 22 June 1967. Standard forage grasses and seeding rates in pounds of pure live seed per acre were: Polar bromegrass 20, Engmo timothy 7, and a non-cultivar commercial lot of meadow foxtail 20; for the native grasses the seeding rates were Siberian wildrye 22, slender wheatgrass 12, and arctic wheatgrass 18. Topdressings of N, P_2O_5, and K_2O, respectively, and application dates were: 126-96-48 on 4 April 1968; 84-0-0 on 3 July 1968; and 126-96-48 on 4 April 1969. All plots were harvested in the seeding year on 5 October 1967, on three different schedules during 1968 (identified in Fig. 3), and a uniform evaluation harvest of all plots (to measure effects of 1968 harvest schedules) was taken on 26 June 1969.

Experiment II (Seven grasses harvested on five schedules): Eight grasses were broadcast-seeded 13 June 1969 in a split-plot experimental design with four replications. Grasses planted included the same six used in Exp. I except Garrison creeping foxtail was added and meadow foxtail was not included. Two additional native Alaskan grasses included were bluejoint and polargrass, both seeded at 7 lb/A.

Fertilizer topdressings during the two-year duration of Exp. II supplied N, P_2O_5, and K_2O, respectively, at the following rates in lb/A: 126-96-48 on 21 April 1970, 84-0-0 on 10 July 1970, 126-96-48 on 22 April 1971, and 84-0-0 on 9 July 1971.

All grasses were harvested on five different schedules during 1970 on the dates and frequencies shown in Table 1. In 1971, all plots were harvested on two dates, 6 July and 15 September. Polargrass yields were low due to stands being marginal and general moisture deficit (Fig. 1); therefore, yields of that grass were not recorded in 1970.

Experiment III (Seven grasses, five N rates, harvested twice per year): The grass plots established in 1969 and utilized during 1970 and 1971 for Exp. II were used also for Exp. III during 1972 through 1974. The effects of different harvest frequencies during 1970 had disappeared by the second cutting in 1971 (Table 1), the year in which all plots were harvested uniformly on two dates.

However, all plots of Engmo timothy, severely injured during the winter of 1970-71, winterkilled completely during the winter 1971-72 and could not be included in Exp. III. Plots of polargrass, however, judged to have stands too sparse to include in Exp. II, had produced considerably larger plants by peripheral growth of tillers during three years of growth and therefore were included in Exp. III.

Five different rates of N were applied to main plots in 1972. Total rates in pounds of N per acre were 54, 108, 162, 216, and 268; 2/3 of each rate was applied on 15 May and 1/3 on 13 July (Table 3). All plots were topdressed uniformly on 12 May 1972 to supply P_2O_5 and K_2O at 112 and 52 lb/A, respectively.

In the two subsequent years all plots were fertilized uniformly and harvests were continued (a) to determine any carryover effects of N applications in 1972 on yields in 1973, and (b) to determine winterhardiness and persistence of grasses through the sixth year (1974). Topdressings applied 16 April 1973 and 17 April 1974 supplied N, P_2O_5, and K_2O at 126, 96, and 48 lb/A, respectively; ammonium nitrate topdressed 12 July 1973 and 1 July 1974 supplied N at 84 lb/A.

All plots were harvested twice each year in Exp. III except that severe drought conditions during 1974 (Fig. 1) so restricted grass regrowth that no appreciable herbage developed on plots to provide a second cutting. Harvest dates in Exp. III were 29 June and 18 September in 1972; 5 July and 5 September in 1973; and 25 June in 1974.

RESULTS AND DISCUSSION

Experiment I (Six grasses harvested two, three, and four times per year)

Seeding Year: All grasses established well with above-normal precipitation in 1967 (Fig. 1). All developed full stands except slender wheatgrass; a limited seed supply necessitated a lighter-than-desired seeding rate resulting in a sparse stand. When all plots were harvested uniformly for forage on 5 October of the seeding year, grass heights were measured and a 12-plot mean yield was derived for each. Heights of grasses in inches, and oven-dry forage yields were: Polar bromegrass = 22-24", 0.96 T/A; Engmo timothy = leaves 18-20", seed heads 26-28", 1.30 T/A; meadow foxtail = leaves 20-22", seed heads 24-26", 1.13 T/A; Siberian wildrye = 12-14", 0.52 T/A; and arctic wheatgrass 12-14", 0.64 T/A. The relatively sparse stand of slender wheatgrass plants produced leafy rosettes only 4 to 6 inches tall and no forage yield was obtained. These results illustrate that the native Alaskan grasses exhibited slower, less productive growth during the year of establishment than the traditional forage grasses that averaged over one ton of dry matter per acre.

Winter Survival: Both meadow foxtail and Engmo timothy sustained considerable injury during the first winter (Fig. 2). Meadow foxtail was somewhat more injured than Engmo and their thinned and weakened stands produced low first-cut yields in 1968, especially in the 14 June and 28 June harvests (Fig. 3). None of the other grasses showed evidence of winter injury.

Forage Yields Under Three Harvest Schedules

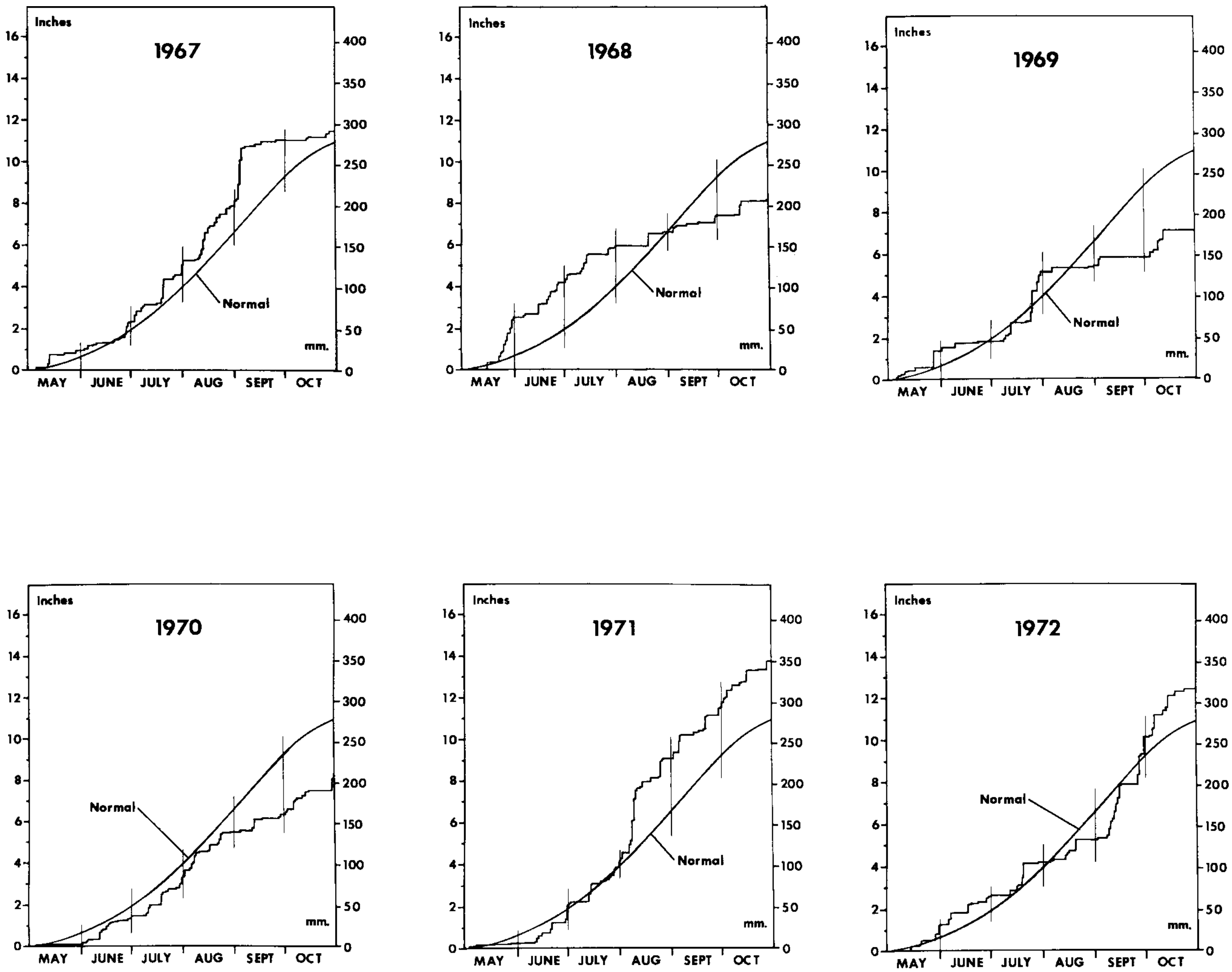
Four harvests per year: Where cut four times per year, two native grasses, Siberian wildrye and arctic wheatgrass, produced significantly more on the first cutting date (4 June) than the other four grasses (Fig. 3); they yielded near one T/A while the others produced less than 1/2 T/A.

In the second of the four cuttings (on 3 July), however, Siberian wildrye and arctic wheatgrass were surpassed significantly in yield by all but Polar bromegrass. Native slender wheatgrass was the highest yielder in the second cutting but produced little in the last two cuttings (29 July and 13 Sep.).

The winter-injured stands of Engmo timothy and meadow foxtail recovered markedly during the growing season; Engmo was the highest yielder in the third cutting and both outyielded the other four grasses in the final cutting. Except for the relatively good fourth-cutting yields of Engmo and meadow foxtail (mean = 0.51 T/A), the fourth-cut yield of the other four grasses averaged only 0.16 T/A.

Hamilton *et al.* (1969) in Wisconsin and Klebesadel (1992) in a separate study in Alaska similarly reported low fourth-cut yields from grasses. Several factors can contribute to low late-season herbage yields; these include (a) shortening daily photoperiods that decrease the time for photosynthetic (food manufacture) activity, (b) lowering temperatures that cause slowing of metabolic activity, (c) much of the spring-applied fertilizer has been utilized in earlier growth, and (d) perennial plants gradually divert more photosynthate away from vegetative growth and into food-reserve storage. That diversion is a prerequisite to good winter survival because those stored foods provide the energy needed for development of freeze tolerance, for life-support during winter dormancy, and to promote new growth the following spring until renewed photosynthetic activity becomes effective (Smith and Nelson 1985).

The six grasses did not differ significantly in total



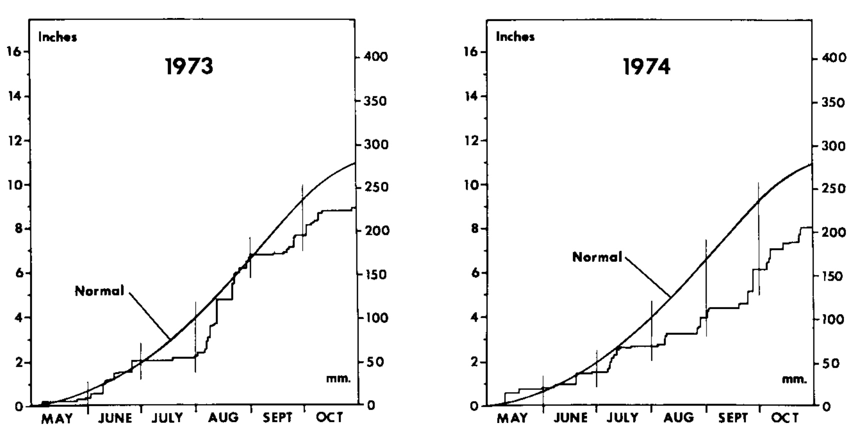


Figure 1. Cumulative precipitation during the period May through October for the years of these experiments. Curved line represents normal cumulative mean and stepped line shows cumulative precipitation actually received each year.

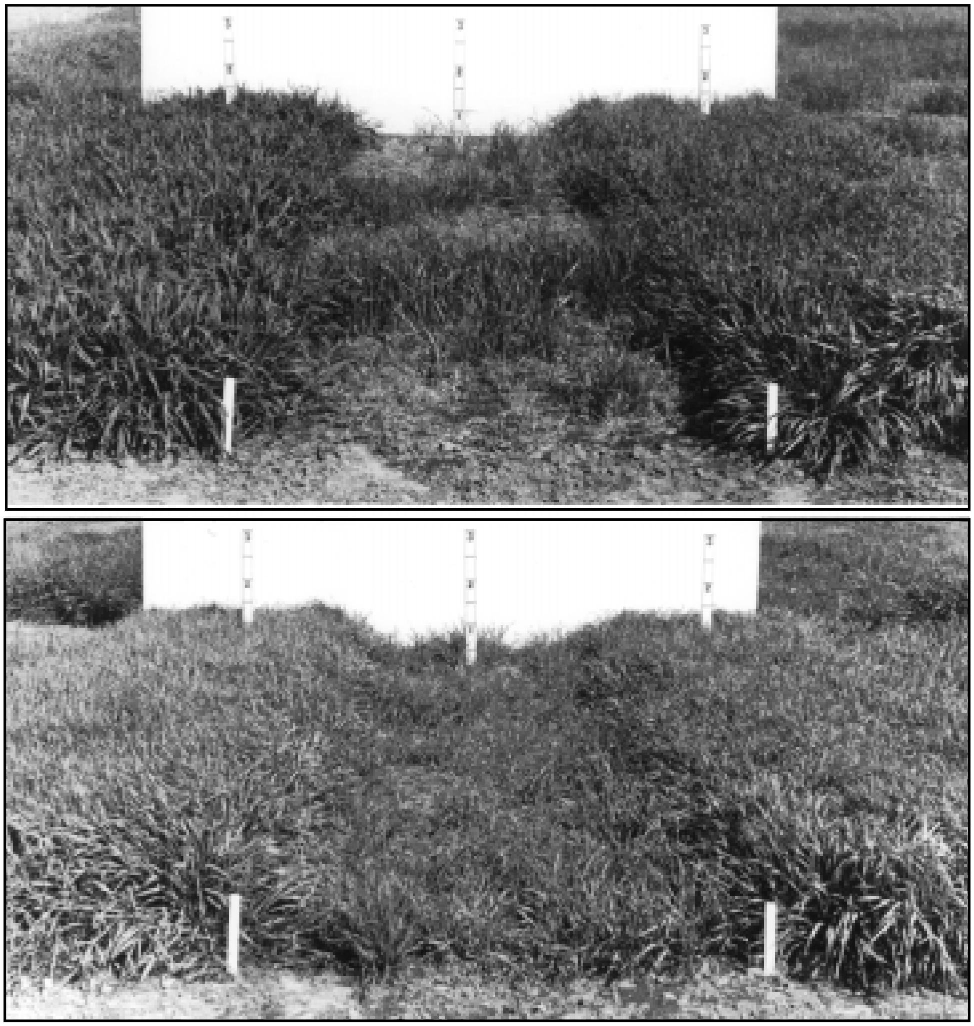


Figure 2. Comparative winter survival and vigor of spring growth of grasses in Experiment I seeded 22 June 1967 and photographed 4 June 1968 in year of differential harvests. Grasses in upper photo (left to right): Native Siberian wildrye, introduced meadow foxtail, and native arctic wheatgrass. In lower photo, winter-injured center plot is introduced Engmo timothy and left and right plots are native arctic wheatgrass. Numbers on white stake in center of each plot indicate height in feet.

yields under the four-cutting schedule, though Engmo tended to be the highest yielder at 2.49 T/A and Polar lowest at 1.76 T/A.

Three harvests per year: With the 3-cut frequency, native Siberian wildrye and arctic wheatgrass again were significantly higher in first-cut (14 June) yield than the other four grasses (Fig. 3). The winter-injured Engmo timothy and meadow foxtail tended to be lowest in first-cut yield in this cutting schedule also, though they were not significantly lower than Polar brome or native slender wheatgrass.

Engmo timothy yielded 1.76 T/A in the second (29 July) cutting, significantly more than the other four grasses which averaged 1.03 T/A. In the final (13 Sep.) cutting, meadow foxtail yielded significantly more than all the other grasses; all five other grasses produced very small yields.

At near 3 T/A in total yield from three cuttings, Siberian wildrye and arctic wheatgrass yielded significantly more than meadow foxtail and slender wheatgrass (which averaged 2.24 T/A), but they did not surpass Polar and Engmo significantly; the latter two were virtually equal in total yield at 2.6 T/A.

Two harvests per year: With the 2-cut frequency, Siberian wildrye surpassed all three cultivated grasses in first-cutting (28 June) yield at 3.4 T/A (Fig. 3). The two native wheatgrasses surpassed Engmo and meadow foxtail significantly in first-cut yield, but they were not significantly lower than Siberian wildrye nor higher than Polar brome. The stand of slender wheatgrass, that had been considered less dense than ideal, increased markedly in first-cut yield by 28 June, compared to lower yields produced in the first cuts (4 June and 14 June) of the other two schedules.

In the second (13 Sep.) harvest of the 2-cut schedule, Engmo and Polar produced most at 2.13 and 1.83 T/A, respectively, and slender wheatgrass least, at 0.97 T/A. Average second-cutting yield for all six grasses was 1.52 T/A.

Total yields with the 2-cut schedule ranged from a high of 4.80 T/A for Siberian wildrye to 2.53 T/A for meadow foxtail. The other four grasses were intermediate in total yield; Polar brome and arctic wheatgrass were similar at 4.16 T/A, and Engmo timothy and slender wheatgrass, about equal, averaged 3.58 T/A.

In general, all grasses produced highest total yields with two cuttings and lowest totals with four cuttings. However, differences in total yields between the 3- and 4-cut schedules were not as great as between those and the higher yields from two cuttings. Other investigators similarly have reported the common pattern of higher total dry-matter yields from infrequent harvests than from more frequent cuttings (Bird 1943; Carter and Law 1948; Fairey 1991; Kunelius *et al.* 1976).

Differences among the six grasses in total yields were greater with two cuttings than with the other two harvest frequencies. Total yields of meadow foxtail were least affected by different cutting frequencies of all grasses compared. That behavior is in general agreement with the results of Fairey (1991) in Alberta who found meadow foxtail to yield approximately as much with four cuttings as with two. Another similarity between the Alberta

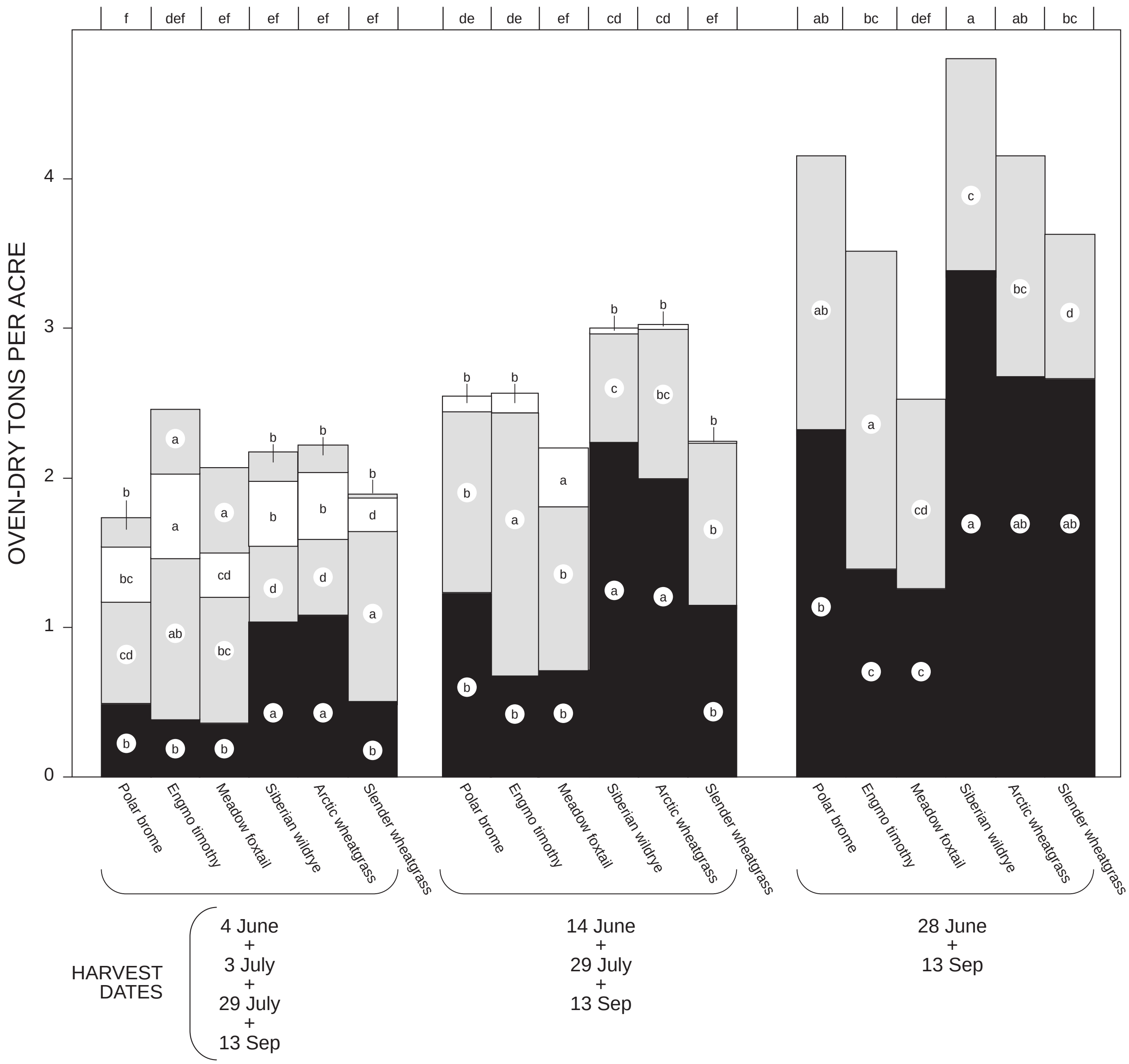


Figure 3. Forage yields of six grasses produced under three harvest frequencies. Basal (black) portion of each bar is yield from first cutting, and progressively higher segments are yields from successively later cuttings. Within each harvest frequency, similarly shaded graph bar segments not containing the same letter differ significantly (5% level) using Duncan's Multiple Range Test. Letters across top of graph are for total yields and those indications of statistical significance are for comparisons over the entire experiment. (Experiment I).

report and the present study was that total yield of smooth bromegrass from four cuttings per year was about half the total yield from two cuttings (Fig. 3).

Other reports from this station (Klebesadel 1992, 1994) illustrate that when bromegrass is harvested four times per year, an early first cutting prior to the fully headed stage interrupts the quite remarkable herbage production characteristic of that grass during the month of June in this area. As a result of interrupting that initial growth period with the first of four cuttings in the present study, the total yield from all four harvests was less than the first cutting on 28 June with the 2-cut treatment (Fig. 3).

Forage Yields in Third-Year Uniform-Evaluation Harvest: Differences among grasses and harvest schedules, as indicated by yields in the third-year harvest of all plots on 26 June, were minor from a statistical viewpoint. Only one difference was significant—Polar brome that had been cut twice yielded significantly more in the first cutting of the following year than arctic wheatgrass that had been cut three times (Fig. 4).

There were, however, strong indications that the various grasses were differentially influenced by the three different harvest frequencies. All grasses except Engmo timothy seemed favored (produced highest third-year yields) where they had been cut only twice the previous year. Engmo, in contrast, showed evidence of increasingly higher yields in the third year where it had been harvested more frequently in the second year. That trend was totally opposite of Polar bromegrass that produced progressively lower yields where it had been harvested more frequently. Marten and Hovin (1980) in Minnesota reported that bromegrass persisted poorer with four cuts per year than with three or two.

A third pattern of response to harvest frequencies in the present study was apparent in the other four grasses; all showed evidence of a similar response to harvest frequencies, but in a pattern different from Polar and Engmo. Final-year yields of meadow foxtail and the three native grasses showed that all were highest yielding where they had been cut only twice the previous year but, somewhat surprisingly, all showed evidence of tolerating three cuttings less well than four (Fig. 4).

The better tolerance of bromegrass to infrequent cutting and timothy to the most frequent harvest schedule parallels findings for those two grasses in the Allegheny Highlands in West Virginia (Jung *et al.* 1974). They stated that their results on grass persistence and yield-distribution responses at the high altitude site were different from those commonly reported for lower elevations, however, and they attributed those differences to "less temperature and moisture stress" (i.e., cooler temperatures and abundant precipitation at the higher altitude).

Experiment II (Seven grasses harvested on five schedules)

All grasses established well for Experiment II except for relatively sparse stands of polargrass. All grasses showed excellent winter survival following the first winter after establishment except Engmo timothy (Fig. 5). The winter-injured Engmo stands produced light forage yields in early and mid-June of the year of different harvest schedules but, with rapid recovery, produced yields equivalent to the other grasses by late June and early July (Table 1)

Four harvests per year: Siberian wildrye surpassed all other grasses except Polar brome in first-cut yield on 8 June; their yields were 0.90 and 0.81 T/A, respectively (Table 1). Engmo timothy and slender wheatgrass tended to be lowest yielders in that cutting, averaging only 0.35 T/A.

At the second cutting on 14 July, mean yield of all grasses was 0.44 T/A and differences were not significant. At the third cutting (10 Aug.), the three cultivated grasses (Polar, Engmo, Garrison) and arctic wheatgrass produced significantly more than Siberian wildrye, slender wheatgrass, and bluejoint.

In the final of four harvests (23 Sep.), there was a clear division between cultivated and native grasses with Polar, Engmo, and Garrison yielding significantly more than the four native grasses; however, all yields were modest and the mean for all seven grasses was only 0.24 T/A.

In total-year yields for four cuttings, slender wheatgrass was significantly lower than all other grasses except bluejoint. The three cultivated grasses and Siberian wildrye were the highest producers and all yielded slightly over 2 T/A.

Three harvests per year: In the first of three cuttings

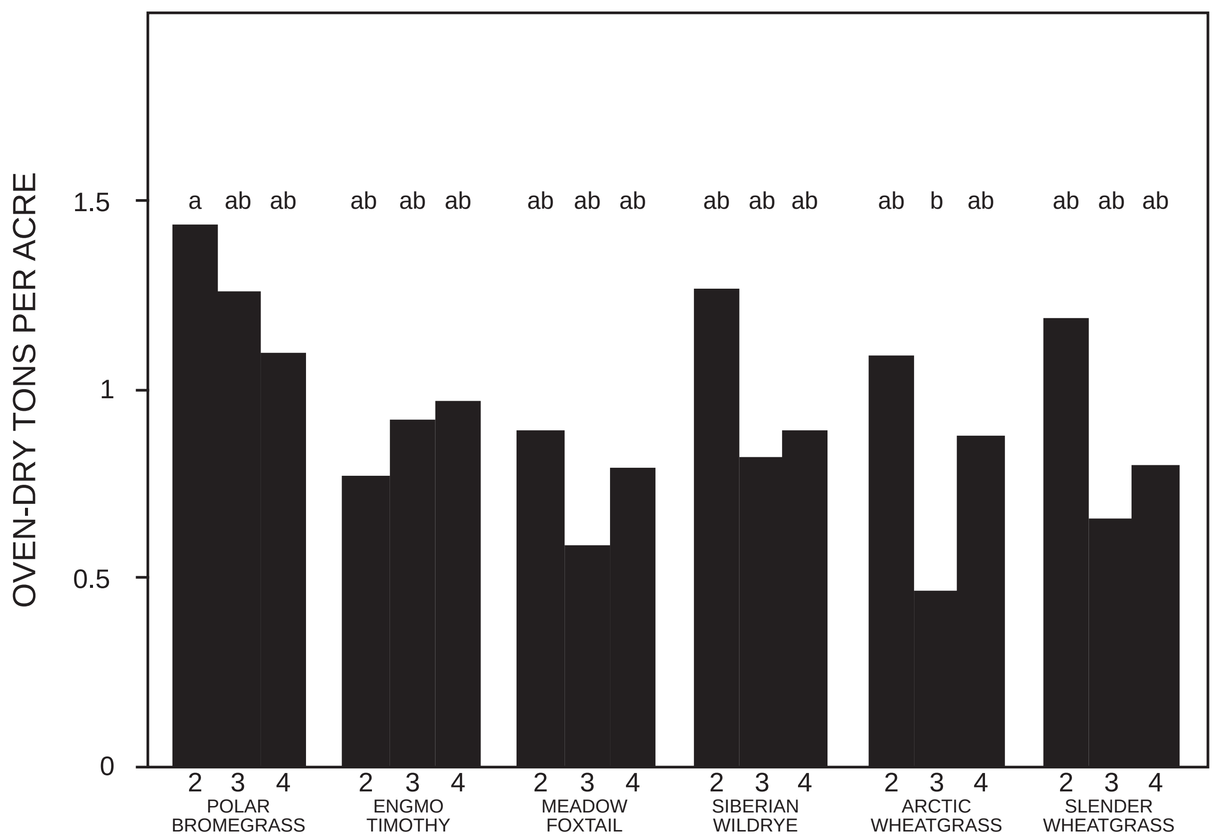


Figure 4. Forage yields of six grasses on 26 June in a uniform-evaluation harvest in the year following the differential harvests depicted in Figure 3. This uniform-evaluation harvest compared effects on grasses of the three harvest frequencies of the previous year; the number under each bar denotes the number of harvests during the previous year. Forage-yield means not having the same letter above their graph bars differ significantly (5% level) using Duncan's Multiple Range Test. (Experiment I).

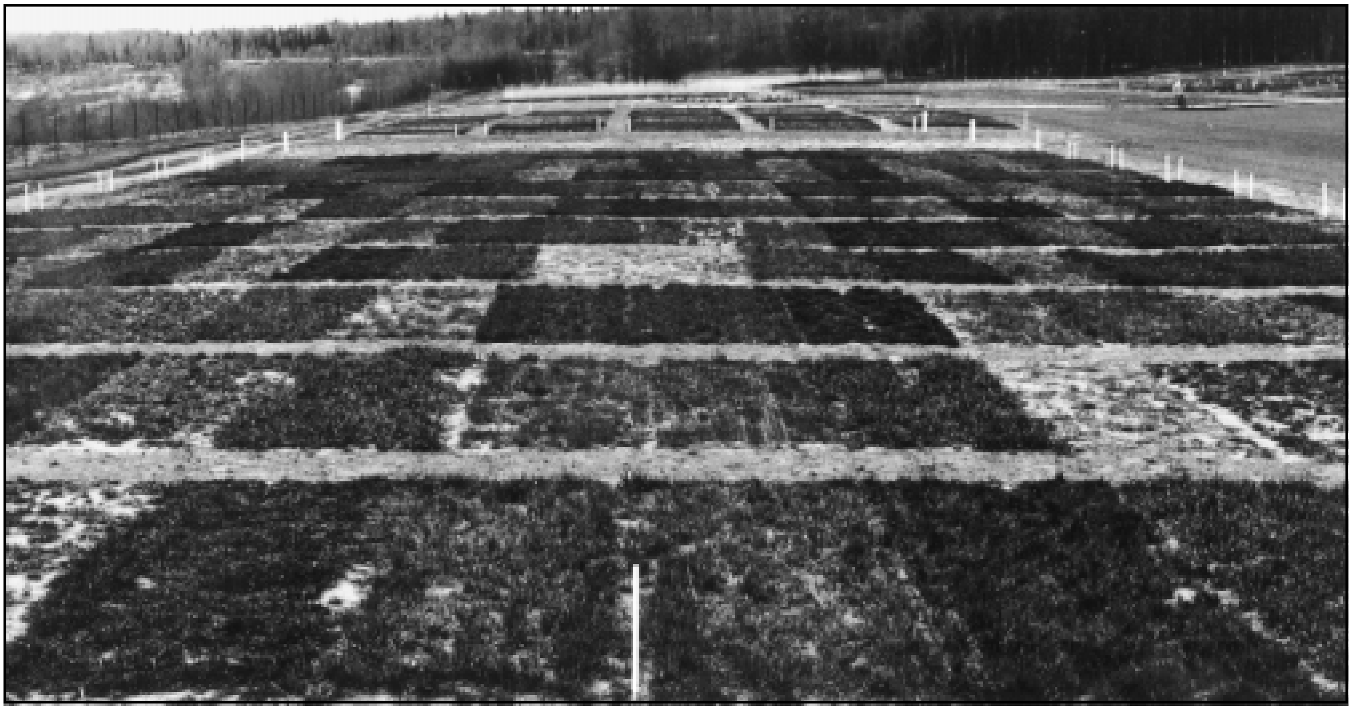


Figure 5. Overall view of grass plots used in Experiments II and III showing spring growth on 13 May of plots seeded the previous year on 13 June. Lightest-appearing plots are those of winter-injured Engmo timothy and thin stands of polargrass.

(harvested 16 June), Siberian wildrye yielded 1.53 T/A, significantly more than Engmo and slender wheatgrass, but not significantly more than Polar, Garrison, arctic wheatgrass or bluejoint (Table 1).

There were no significant differences among grasses in the second cutting on 24 July, and the mean yield was only 0.47 T/A. At the final of three cuttings on 23 September, all three cultivated grasses again yielded significantly more (mean = 1.41 T/A) than the four native grasses (mean = 0.90 T/A).

In total yields for three cuttings, slender wheatgrass again was the lowest (1.78 T/A), and significantly lower than all grasses except arctic wheatgrass and bluejoint. The latter two grasses were intermediate in yield (mean = 2.24 T/A) between slender wheatgrass and the four highest yielders (mean = 2.90 T/A); however, they did not differ significantly from either the highest or lowest yielders. Polar was highest in total yield for three cuts (3.28 T/A) but not significantly higher than Engmo, Garrison, or Siberian wildrye.

Two harvests per year: The three different schedulings of two cuts per year had the same final harvest date (23 Sep.) but differed in the date of the first harvest (Table 1). Each succeeding first-cut date was about two weeks later than the previous one; therefore, each later first-harvest date lengthened the initial growing period for the grasses, but shortened the growth interval between the two harvests for the year. Growth periods between first and second cuttings were 105, 91, and 78 days when first cuttings were taken 8 June, 23 June, and 7 July, respectively.

Two cuttings—early first cut: With the earliest (8 June) first cutting, mean yield of all grasses was only 0.82 T/A (Table 1). Siberian wildrye at 1.21 T/A yielded significantly more than Engmo, slender wheatgrass, and bluejoint, but the wildrye yield was not significantly higher than Polar, Garrison, and arctic wheatgrass.

In the second harvest of that 2-cut schedule, Engmo (lowest in the first harvest) yielded 2.80 T/A, significantly surpassing all other grasses. Polar yielded 2.41 T/A, significantly more than the other five grasses; mean yield of those was 1.75 T/A and there were no significant differences among them.

Total yields for the two harvests ranged from a high of 3.42 T/A (Polar) to a low of 2.41 T/A (bluejoint). Polar and Engmo totals were significantly higher than all native grasses except Siberian wildrye.

Two cuttings—mid-date first cut: With the first cut on 23 June, mean yield of all grasses (1.29 T/A) was about 50% higher than the mean yield two weeks earlier (Table 1). Siberian wildrye and Polar brome produced highest and similar yields (mean = 1.63 T/A), significantly more than Engmo and Garrison but not significantly more than the four native grasses which averaged 1.38 T/A.

In the second cutting of that schedule, all grasses yielded less than in the above-discussed, 2-cut schedule where the first cutting had been taken two weeks earlier. Engmo, again, was the highest yielder (2.19 T/A) in the second cutting, surpassing all other grasses significantly. Differences among the other grasses were modest; yields ranged from a high of 1.76 T/A (Polar) to a low of 1.14 T/A (slender wheatgrass).

In total yields for the two harvests, Polar was highest at 3.40 T/A, surpassing all other grasses significantly except Engmo (3.27 T/A). Engmo's total, significantly higher than Garrison and slender wheatgrass, was not

Table 1. Oven-dry forage yields of seven perennial grass species (three cultivars + four native Alaskan strains) as influenced by five different harvest schedules, and effects of those harvest schedules on grasses as measured by uniform evaluation harvests of all plots on 6 July and 15 September of the following year. (Experiment II).

Harvest schedules and grasses	Year of different harvest schedules—1970					Uniform harvest of all plots subsequent year (1971)	
	Tons per acre						
4 harvests per year:	8 June	14 July	10 Aug	23 Sep	Total	6 July	15 Sep
Polar bromegrass	0.81 ab[1]	0.38 a	0.81 a	0.26 b	2.26 j-n	0.69 jk	1.80 a
Engmo timothy	0.38 de	0.45 a	0.74 a	0.44 a	2.01 lmno	Tr[2]	1.20 bc
Garrison foxtail	0.59 bcd	0.36 a	0.77 a	0.51 a	2.23 j-n	0.46 k	1.76 a
Siberian wildrye[3]	0.90 a	0.53 a	0.48 b	0.12 c	2.03 k-o	1.57 cdef	0.71 f
Arctic wheatgrass[3]	0.66 bc	0.39 a	0.80 a	0.12 c	1.97 mno	1.53 cdef	1.08 cde
Slender wheatgrass[3]	0.32 e	0.52 a	0.36 c	0.09 c	1.29 p	1.72 abcd	0.62 f
Bluejoint[3]	0.55 cde	0.42 a	0.39 bc	0.14 c	1.50 op	1.35 efgh	1.01 cde
Mean	0.60	0.44	0.62	0.24	1.90	1.05	1.17
3 harvests per year:	16 June	24 July		23 Sep			
Polar bromegrass	1.31 ab	0.61 a		1.36 a	3.28 cdef	0.45 k	1.43 b
Engmo timothy	0.90 b	0.43 a		1.50 a	2.83 d-j	Tr	0.17 g
Garrison foxtail	1.05 ab	0.38 a		1.37 a	2.80 d-j	0.52 k	1.85 a
Siberian wildrye[3]	1.53 a	0.44 a		0.70 b	2.67 f-m	1.65 cde	0.72 f
Arctic wheatgrass[3]	1.00 ab	0.44 a		0.81 b	2.25 j-n	1.58 cdef	1.17 bc
Slender wheatgrass[3]	0.85 b	0.54 a		0.39 c	1.78 nop	1.84 abc	0.61 f
Bluejoint[3]	0.99 ab	0.44 a		0.80 b	2.23 j-n	1.33 efgh	1.04 cde
Mean	1.09	0.47		0.99	2.55	1.05	1.00
2 harvests per year—early first cut:	8 June			23 Sep			
Polar bromegrass	1.01 ab			2.41 b	3.42 cd	1.08 hi	1.80 a
Engmo timothy	0.52 b			2.80 a	3.32 cdef	Tr	0.66 f
Garrison foxtail	0.81 ab			1.88 c	2.69 f-l	0.89 ij	1.80 a
Siberian wildrye[3]	1.21 a			1.65 c	2.86 d-j	1.69 bcd	0.82 def
Arctic wheatgrass[3]	0.85 ab			1.72 c	2.57 g-m	1.46 def	1.18 bc
Slender wheatgrass[3]	0.67 b			1.77 c	2.44 h-n	1.96 ab	0.65 f
Bluejoint[3]	0.68 b			1.73 c	2.41 h-n	1.43 defg	1.19 bc
Mean	0.82			1.99	2.82	1.22	1.16
2 harvests per year—mid-date first cut:	23 June			23 Sep			
Polar bromegrass	1.64 a			1.76 b	3.40 cde	1.14 ghi	1.83 a
Engmo timothy	1.08 bc			2.19 a	3.27 c-g	WK[4]	—
Garrison foxtail	0.80 c			1.50 bcd	2.30 i-n	0.86 ij	1.86 a
Siberian wildrye[3]	1.62 a			1.28 cd	2.90 d-j	1.26 fgh	0.68 f
Arctic wheatgrass[3]	1.17 abc			1.55 bc	2.72 e-k	1.50 def	1.15 bc
Slender wheatgrass[3]	1.31 ab			1.14 d	2.45 h-n	2.02 a	0.66 f
Bluejoint[3]	1.40 ab			1.58 bc	2.98 c-i	1.60 cde	1.29 bc
Mean	1.29			1.57	2.86	1.20	1.07
2 harvests per year—late first cut:	7 July			23 Sep			
Polar bromegrass	2.56 a			1.96 a	4.52 a	0.88 ij	1.79 a
Engmo timothy	2.26 a			1.84 ab	4.10 ab	WK	—
Garrison foxtail	1.42 b			1.67 b	3.09 c-h	0.66 jk	1.80 a
Siberian wildrye[3]	2.49 a			1.12 d	3.61 bc	1.45 defg	0.77 ef
Arctic wheatgrass[3]	2.03 ab			1.15 cd	3.18 c-g	1.60 cde	1.07 cde
Slender wheatgrass[3]	1.88 ab			0.77 e	2.65 f-m	1.97 ab	0.70 f
Bluejoint[3]	1.84 ab			1.34 c	3.18 c-g	1.52 cdef	1.26 bc
Mean	2.07			1.41	3.48	1.15	1.06

[1]Means not followed by a common letter are significantly different (5% level) using Duncan's Multiple Range Test. For individual differential harvests, comparisons are among each 7-strain data set in a column; for total yields and each uniform evaluation harvest during subsequent year, comparisons are among all 35 means within each column.

[2]Trace amount of herbage inadequate for harvestable yield.

[3]Strain composited from collections within Alaska.

[4]No further yields from totally winterkilled stands.

Table 2. Percent IVDMD in seven perennial grass species (three cultivars + four native Alaskan strains) as influenced by five different harvest schedules at the Matanuska Research Farm. For the 8 June harvest that appears in both the 4-cut and one of the 2-cut schedules, one laboratory determination was performed, thus the same values appear in both schedules. (Experiment II).

Harvest schedules and grasses	Harvest dates - 1970			
	% IVDMD			
4 harvests per year:				
	8 June	14 July	10 Aug	23 Sep
Polar bromegrass	75.1 a[1]	75.4 a	72.4 c	78.4 b
Engmo timothy	74.7 a	75.0 a	75.7 a	83.0 a
Garrison foxtail	75.4 a	74.6 a	75.1 ab	78.9 b
Siberian wildrye[2]	75.4 a	72.7 ab	73.5 bc	73.5 c
Arctic wheatgrass[2]	73.4 a	72.0 ab	73.5 bc	72.1 c
Slender wheatgrass[2]	73.2 a	73.5 a	72.6 c	73.0 c
Bluejoint[2]	69.3 b	69.4 b	72.8 c	73.1 c
Mean	73.8	73.2	73.7	76.0
3 harvests per year:				
	16 June	24 July		23 Sep
Polar bromegrass	72.3 a	71.9 bc		72.4 bc
Engmo timothy	74.5 a	77.8 a		79.4 a
Garrison foxtail	73.6 a	73.8 b		72.7 b
Siberian wildrye[2]	72.3 a	73.2 b		69.0 d
Arctic wheatgrass[2]	71.8 a	71.7 bc		64.1 e
Slender wheatgrass[2]	73.1 a	68.1 d		69.9 cd
Bluejoint[2]	67.7 b	69.4 cd		68.0 d
Mean	72.2	72.3		70.8
2 harvests per year; early first cut:				
	8 June			23 Sep
Polar bromegrass	75.1 a			61.5 c
Engmo timothy	74.7 a			72.9 a
Garrison foxtail	75.4 a			65.8 b
Siberian wildrye[2]	75.4 a			57.4 d
Arctic wheatgrass[2]	73.4 a			53.6 e
Slender wheatgrass[2]	73.2 a			54.5 de
Bluejoint[2]	69.3 b			54.1 e
Mean	73.8			60.0
2 harvests per year; mid-date first cut:				
	23 June			23 Sep
Polar bromegrass	69.1 a			65.9 c
Engmo timothy	70.4 a			77.5 a
Garrison foxtail	69.8 a			70.8 b
Siberian wildrye[2]	69.5 a			64.9 c
Arctic wheatgrass[2]	67.4 ab			55.7 d
Slender wheatgrass[2]	67.4 ab			66.5 c
Bluejoint[2]	64.0 b			58.6 d
Mean	68.2			65.7
2 harvests per year; late first cut:				
	7 July			23 Sep
Polar bromegrass	63.8 b			67.6 bc
Engmo timothy	66.0 b			78.0 a
Garrison foxtail	68.8 a			70.2 b
Siberian wildrye[2]	65.7 b			70.3 b
Arctic wheatgrass[2]	64.8 b			61.7 d
Slender wheatgrass[2]	69.5 a			69.0 b
Bluejoint[2]	60.8 c			64.8 c
Mean	65.6			68.8

[1]Within each 7-cultivar data set in a column, means not followed by a common letter are significantly different (5% level) using Duncan's Multiple Range Test.

[2]Composited strains from collections within Alaska.

significantly higher than bluejoint (2.98 T/A), Siberian wildrye (2.90 T/A), or arctic wheatgrass (2.72 T/A).

Two cuttings—late first cut: With the first harvest on 7 July, mean yield of all grasses (2.07 T/A) was 60% higher than the yield obtained in the previously discussed schedule where the first cut was two weeks earlier on 23 June (Table 1). There were no significant differences in this harvest except that Polar, Engmo, and Siberian wildrye (mean = 2.44 T/A) surpassed Garrison (1.42 T/A) significantly.

In the second harvest of this schedule, all three cultivated grasses produced significantly higher yields (mean = 1.82 T/A) than the four native grasses (mean = 1.10 T/A). With this 2-cut schedule, which provided 13 fewer days for growth between the first and second cuttings than the previous 2-cut schedule, all grasses except Polar brome produced lower yields in the second cutting.

In total yields for the two harvests, Polar at 4.52 T/A again was significantly higher than all other grasses except Engmo at 4.10 T/A. All seven grasses surpassed 3 T/A except slender wheatgrass at 2.65 T/A; however, slender was not significantly lower than Garrison, arctic wheatgrass, or bluejoint. Two-cut total yields for this schedule were generally higher for most grasses than for either of the other 2-cut schedules or for the 3- or 4-cut frequencies.

Comparing total annual yields for all five harvest schedules, salient observations may be summarized as follows:

Cutting schedule	Mean total yield (all grasses)	Yield observations
4 cuts	1.90	No grass yielded over 2.26 T/A
3 cuts	2.55	Only Polar yielded over 3 T/A
2 cuts - early 1st cut	2.82	Only Polar and Engmo yielded over 3 T/A
2 cuts - mid-date 1st cut	2.86	Only Polar and Engmo yielded over 3 T/A
2 cuts - late 1st cut	3.48	Only Polar and Engmo yielded over 4 T/A

Percent IVDMD: Digestibility of grasses (as measured by *in vitro* dry-matter disappearance) was highest when grasses were harvested at the most immature stages of growth (4 cuts per year), never dropping below 73% (mean for 7 grasses) and averaging 74.2% (Table 2). With the less frequent 3-cut schedule, mean percents IVDMD for all 7 grasses were slightly lower, ranging between 70.8% and 72.3% with an overall mean of 71.8%. Mean percent IVDMD for the three different 2-cut schedules was still lower at 67.0%. Allinson *et al.* (1969) and Marten and Hovin (1980) also reported higher mean percent IVDMD values for smooth bromegrass and other grasses harvested three or four times per year than with less frequent harvests. Similarly, Kunelius *et al.* (1976) in eastern Canada reported highest percent IVDMD in timothy harvested four times per year and progressively lower percents with three and two harvests per year.

Mowat *et al.* (1965) and Pritchard *et al.* (1963) noted that digestibility declined progressively with advancing maturity in both leaves and stems, but the decline was more rapid in stems. This helps to explain the higher digestibility noted with more frequent harvests of younger, leafier herbage in the present study and in other reports cited above.

Mean percent IVDMD for the seven grasses in the present study declined regularly with progressively later first-cutting harvests in the various schedules (percents IVDMD = 73.8%, 72.2%, 68.2%, 65.6%, respectively, for first harvest dates of 8 June, 16 June, 23 June, 7 July).

A clear pattern was apparent also in the 7-grass-mean percent IVDMD in the final (23 Sep.) harvests among the various schedules; the longer the growth period prior to the final harvest, the lower the mean percent IVDMD:

Growing days between previous harvest and final 23 Sep. harvest	Schedule	Mean % IVDMD for 7 grasses
45	4-cut	76.0
61	3-cut	70.8
78	2-cut (late 1st cut)	68.8
91	2-cut (mid-date 1st cut)	65.7
105	2-cut (early 1st cut)	60.0

Considering individual grasses, bluejoint usually was the lowest in percent IVDMD in most harvests, often to a statistically significant extent. This is in general agreement with a report by Mitchell (1987) wherein bluejoint was compared with eight other grass species. In the present study, arctic wheatgrass generally was inferior to most other species in the final harvest on 23 September with most harvest schedules.

When other differences were significant in the first cutting, they occurred at the latest (7 July) harvest; then Garrison foxtail and slender wheatgrass surpassed all other grasses in percent IVDMD.

Engmo timothy surpassed all other grasses significantly in percent IVDMD in the third harvest (10 Aug.) of the 4-cut schedule, in the second harvest (24 July) of the 3-cut schedule, and in the final harvest (23 Sep.) of all five different harvest schedules.

Mitchell (1982, 1986, 1987) in Alaska, and Collins and Casler (1990) in Wisconsin, also found timothy to be high in percent IVDMD among several grass species compared at each location. Kunelius *et al.* (1974) in eastern Canada, however, reported little difference between Climax timothy and Saratoga bromegrass in digestibility in either the primary growth harvested at various stages of development or in their regrowths.

The progressive decline in digestibility of herbage with advance in maturity noted in the present study parallels similar findings in other reports (Calder and MacLeod 1968; Collins and Casler 1990; Kunelius *et al.* 1974; Martin and Hovin 1980; Mitchell 1987; Pritchard *et al.* 1963; Waldie *et al.* 1983).

Uniform evaluation harvest the following year to measure residual effects of different harvest sched-

ules: The winter of 1970-71 imposed relatively severe stresses; in this and several other experiments underway at the time, crop injury was considerable, ranking it as one of the most injurious winters of a 3-decade period.

Engmo timothy was the least winterhardy and therefore most injured of the seven grasses; Engmo stands winterkilled completely in two of the 2-cut schedules and were so severely damaged under the other three harvest schedules that only an unharvestable "trace" amount of herbage was present at the first uniform-evaluation harvest on 6 July (Table 1).

With gradual recovery of those severely injured stands, Engmo yield in the second evaluation harvest (on 15 Sep.) was much higher (1.20 T/A) where it had been cut four times the previous year than where it had been cut three or two times. That response of Engmo was consistent with its response to harvest schedules in Exp. I where it also showed evidence of tolerating four cuts better than three or two.

That evidence of considerable tolerance of Engmo timothy to frequent cutting has been noted in other experiments and also where it has occurred as a successfully invasive species in frequently harvested turf consisting primarily of Kentucky bluegrass (*Poa pratensis*). It is believed that the somewhat unique plant morphology of Engmo suits it to frequent cutting.

Smith *et al.* (1986) and Harrison and Hodgson (1939) described timothy grown in the U.S. Midwest as intolerant of frequent defoliation. However, Engmo and certain other timothy cultivars adapted at far-northern latitudes possess a greater profusion of basal leaves than North American strains. Therefore, even with frequent defoliation, those northern cultivars retain a much greater quantity of leaves below the height of cutting than other tall-growing grasses and thus are more capable of continuing active photosynthesis after harvest.

The significance of that unique growth form in certain far-northern timothies, much like that of Kentucky bluegrass and other grasses with an abundance of basal leaves that suits them for turf use, is of importance to the plant's physiology (Graber 1931; Harrison and Hodgson 1939; Smith and Nelson 1985; Smith *et al.* 1986). When tall-growing plants with leaves borne on their culms are clipped to a short stubble, no basal leaves are left in place to continue food manufacture; therefore, they must draw upon previously stored food reserves within the plant to put forth new leaf growth.

Repeated total defoliation consequently not only imposes a period of interrupted food manufacture (photosynthesis), but also causes the plant to draw upon stored reserves to put forth new growth, thus reducing the vigor of such plants (Graber 1931; Harrison and Hodgson 1939; Smith and Nelson 1985). When that penalty of reduced levels of food reserves continues into the autumn winterhardening period, perennial plants thus weakened are predisposed to poor winter survival.

Conversely, plants that retain a functional leaf mass below the height of cutting, such as Engmo and certain other northern timothies, Kentucky bluegrass, and red fescue (*Festuca rubra*), can tolerate frequent harvest (as for green-chop), grazing, or mowing as turf without being weakened. In fact, they may actually benefit from occasional removal of much of the aerial growth to prevent basal leaves from becoming shaded, bleached, and non-functional. When the tall initial growth of Engmo was left in place until 23 June or 7 July in the present experiment, those schedules were more harmful to Engmo (resulting in total winterkill) than where removal of aerial growth was earlier (8 June) with two cuttings, or where it was harvested three or four times.

The other two cultivated grasses, Polar bromegrass and Garrison creeping foxtail, yielded much less in the first uniform-evaluation harvest (6 July) than the four native grasses. Mean first-cut yield of the four native grasses as influenced by all cutting schedules was 1.55 T/A while the mean for Polar and Garrison was only 0.76 T/A. That considerable difference between the low yields of those two cultivated grasses (and cultivated Engmo producing none), versus much higher yields for the four native grasses, was due to the unusually stressful winter causing greater injury to the slightly less hardy cultivated grasses. In contrast, the more winterhardy, subarctic-adapted native grasses sustained no apparent injury.

Furthermore, yields of Polar and Garrison in the uniform evaluation harvest on 6 July indicated that those injured grasses were much more influenced by the five different harvest schedules during the previous year than were the four native grasses. Both Polar and Garrison were adversely affected by the more frequent harvests, producing much less forage on 6 July where they had been cut three or four times during the previous year; Polar seemed unusually disfavored by the 3-cut schedule, producing only 0.45 T/A in the first cut of the following year. Other investigators (Jung *et al.* 1974; Marten and Hovin 1980) similarly have reported poor tolerance of smooth bromegrass to frequent harvests.

Slender wheatgrass, almost always the lowest yielder in each of the five different harvest schedules during the previous year, was the highest yielder in the first-cutting, uniform-evaluation harvest; its mean yield for all five harvest schedules was 1.90 T/A.

The other three native grasses—Siberian wildrye, arctic wheatgrass, and bluejoint—were about equal in yield, and there was little consistent pattern in the influence of the five different harvest schedules during the previous year on yields in the uniform evaluation harvest on 6 July.

Polar and Garrison showed evidence of good recovery during the growing season, almost invariably producing significantly higher yields in the second uniform evaluation harvest on 15 September (mean = 1.77 T/A) than did the four native grasses (mean = 0.92 T/A).

Experiment III (Seven grasses, five N rates, harvested twice per year)

Seven grasses were included in Exp. III, but with a difference from Exp. II. Stands of Engmo timothy had been eliminated by winterkill, but stands of polargrass, seeded originally with the other grasses but judged too thin for inclusion in Exp. II, had thickened sufficiently by enlargement of individual plants to be included in Exp. III.

Table 3. Oven-dry forage yields and percent IVDMD and crude protein in each of two harvests of seven perennial grasses (2 cultivars + 5 native Alaskan strains) as influenced by five rates of applied N, 2/3 of each rate applied in spring, 1/3 applied in mid-summer. (Exp. III).

Rate of N applied[1] (Pounds per acre) 15 May	13 July	Total	Grass	Harvests in 1972: First - 29 June Tons/A	First % IVDMD	First % Crude protein	Second - 18 Sep. Tons/A	Second % IVDMD	Second % Crude protein
36	18	54	Polar bromegrass	0.96 p[2]	68.0 ab	13.3 e-j	0.63 c-h	63.5 abc	9.7 h-m
			Garrison foxtail	1.73 lmn	67.5 abc	9.3 l	0.35 hij	62.5 a-e	9.0 i-m
			Siberian wildrye[3]	1.44 no	66.5 abc	11.8 g-l	0.42 g-j	60.2 b-h	10.4 e-k
			Arctic wheatgrass[3]	1.87 klm	57.8 gh	10.9 jkl	0.51 e-j	52.2 n-r	7.8 m
			Slender wheatgrass[3]	1.50 no	58.2 gh	12.4 f-k	0.21 j	54.5 l-o	11.0 e-i
			Bluejoint[3]	1.95 j-m	54.0 i	12.1 g-k	0.60 c-h	51.7 o-r	9.0 i-m
			Polargrass[3]	2.30 e-i	57.2 ghi	11.6 h-l	0.23 ij	57.5 f-m	10.4 e-k
			Mean	1.68	61.3	11.6	0.42	57.4	9.6
72	36	108	Polar bromegrass	1.32 o	60.7 efg	15.1 def	0.82 cde	58.1 f-l	8.0 lm
			Garrison foxtail	2.02 i-m	59.3 fg	11.3 i-l	0.58 d-h	59.7 c-i	9.2 i-m
			Siberian wildrye[3]	1.70 lmn	60.8 efg	14.5 d-g	0.54 e-i	52.6 n-q	8.7 i-m
			Arctic wheatgrass[3]	2.08 g-k	55.5 hi	12.1 g-l	0.66 c-h	48.7 r	8.4 klm
			Slender wheatgrass[3]	1.69 mn	58.5 gh	15.3 de	0.23 ij	54.0 m-p	12.7 b-e
			Bluejoint[3]	2.32 d-i	51.1 ghi	13.4 e-j	0.60 c-h	50.7 pqr	10.6 e-k
			Polargrass[3]	2.84 ab	58.6 gh	10.7 jkl	0.37 hij	59.5 d-j	10.9 e-i
			Mean	2.00	57.8	13.2	0.54	54.8	9.8
108	54	162	Polar bromegrass	1.35 o	66.3 bc	13.9 e-i	1.23 a	58.7 e-k	9.3 i-m
			Garrison foxtail	2.37 c-h	62.6 def	9.9 kl	0.65 c-h	56.8 h-m	9.8 h-m
			Siberian wildrye[3]	1.71 lmn	68.0 ab	15.1 def	0.67 c-h	57.2 g-m	10.4 e-k
			Arctic wheatgrass[3]	2.17 f-k	66.4 abc	13.9 e-i	0.92 bc	49.1 qr	8.5 klm
			Slender wheatgrass[3]	1.85 klm	67.7 abc	14.2 d-h	0.46 f-j	57.2 g-m	12.4 b-f
			Bluejoint[3]	2.41 c-g	63.9 cde	13.8 e-i	0.73 c-g	51.6 o-r	9.9 g-m
			Polargrass[3]	2.85 ab	66.9 abc	12.0 g-l	0.74 c-g	58.0 f-l	10.4 e-k
			Mean	2.10	66.0	13.3	0.77	55.5	10.1
144	72	216	Polar bromegrass	1.46 no	68.9 ab	14.5 d-g	1.28 a	62.1 a-e	10.1 f-l
			Garrison foxtail	2.42 c-g	68.4 ab	13.1 e-j	0.71 c-g	60.7 b-g	11.8 c-h
			Siberian wildrye[3]	1.72 lmn	70.3 a	21.7 abc	0.71 c-g	60.3 b-h	12.2 c-g
			Arctic wheatgrass[3]	2.45 c-f	66.1 bc	19.8 c	0.92 bc	49.4 qr	8.6 j-m
			Slender wheatgrass[3]	2.05 h-l	66.5 abc	19.8 c	0.55 d-h	55.1 k-o	13.9 bc
			Bluejoint[3]	2.66 a-d	66.4 abc	20.7 bc	0.91 bc	55.7 j-n	10.9 e-j
			Polargrass[3]	2.86 ab	68.4 ab	16.8 d	0.77 c-f	63.8 ab	12.2 c-g
			Mean	2.23	67.9	18.1	0.84	58.2	11.4
180	88	268	Polar bromegrass	1.28 o	67.2 abc	21.7 abc	1.19 ab	63.2 a-d	11.0 d-i
			Garrison foxtail	2.24 f-j	67.9 ab	19.8 c	0.70 c-g	65.4 a	14.0 bc
			Siberian wildrye[3]	2.00 i-m	68.8 ab	22.6 ab	0.59 c-h	61.3 b-f	14.5 ab
			Arctic wheatgrass[3]	2.59 b-e	67.1 abc	23.8 a	0.88 cd	49.0 qr	10.3 f-k
			Slender wheatgrass[3]	2.14 f-k	67.7 abc	23.1 ab	0.22 ij	58.0 f-l	16.4 a
			Bluejoint[3]	2.70 abc	65.2 bcd	23.2 ab	0.81 cde	55.9 i-n	12.3 c-f
			Polargrass[3]	2.94 a	66.9 abc	20.0 c	0.50 e-j	59.5 d-j	13.2 bcd
			Mean	2.27	67.3	22.0	0.70	58.9	13.1

[1]Two thirds of each rate applied 15 May, ⅓ applied 15 July after first cutting.

[2]Within each column, means not followed by a common letter are significantly different (5% level) using Duncan's Multiple Range Test.

[3]Composited strains from collections within Alaska.

Polargrass stands had been harvested on the same five schedules as the other grasses in 1970 and also twice in 1971 in the two uniform-evaluation harvests of Exp. II. However, yields for polargrass were not recorded for the five harvest schedules in 1970 nor for the first cutting on 6 July 1971. Mean oven-dry yield for polargrass (20 plots) in the second cutting of all plots on 15 September 1971 was 1.21 T/A, exceeding the means for all other grasses (Table 1) and confirming that polargrass stands were fully productive and usable for Exp. III.

Dry-matter yields: In the year of five different N rates, all seven grasses generally produced substantially more first-harvest forage with the 72 lb/A rate of N (applied in spring) than with the lowest rate (36 lb/A) (Table 3). With increasing rates of N above 72 lb/A, however, grasses differed in their responses, though the yield increases often were not statistically significant. Those that showed little increase in first-cut yield with N rates above 72 lb/A in spring were Polar brome and polargrass; however, they differed considerably in yield. Mean first-cut yield of polargrass for the four highest rates of N was 2.87 T/A while for Polar it was only 1.35 T/A.

A second pattern of response to N rates was noted in Garrison creeping foxtail; first-cut yields showed small but continuous increases with increasing spring N rates up to the 108 lb/A rate, but showed no improvement with the next two higher rates.

A third pattern of response occurred with Siberian wildrye, bluejoint, and the two wheatgrasses wherein a general trend of continued increase in first-cut yield resulted from each additional increment of added N; thus the highest yield occurred with the highest N rate.

In the second cutting, increasing N rates resulted in the greatest yield increases in Polar brome (range=0.63 to 1.28 T/A), and the smallest increases in Siberian wildrye (range=0.42 to 0.71 T/A). The other grasses were intermediate between those extremes. No substantial benefit toward increased second-cutting yields occurred with mid-season N rates above 54 lb/A, and the highest mid-season rate (88 lb/A) generally resulted in lower yields than the second-highest rate (72 lb/A), significantly so with slender wheatgrass.

In general, the native grasses were as responsive (and in some instances more so) to increasing N rates as the cultivated grasses. Averaged over all N rates, the grasses ranked as follows in forage yield: polargrass > bluejoint > arctic wheatgrass > Garrison creeping foxtail > Polar brome = Siberian wildrye > slender wheatgrass.

A noteworthy phenomenon not shown in the tabular data was the considerably lower percent dry matter in the herbage of polargrass in contrast to the other grasses. That characteristic was noted earlier (Klebesadel 1969a) but not with as many grasses nor at different rates of N fertilization. The marked difference between polargrass and the others is apparent in Figure 6 which also shows changes in percent dry matter in first-cutting herbage of all grasses with increasing rates of N fertilization.

All grasses showed a general decline in percent dry matter with increasing N rates but, except for Garrison foxtail, most of the decline occurred up to the 108 lb/A rate. The much lower percent dry matter (greater succulence) in polargrass herbage than in the other grasses may be related to habitat sites generally occupied by this grass in nature; it tends to occur in sites well supplied with moisture.

Percent IVDMD: Mean percent IVDMD for all seven grasses

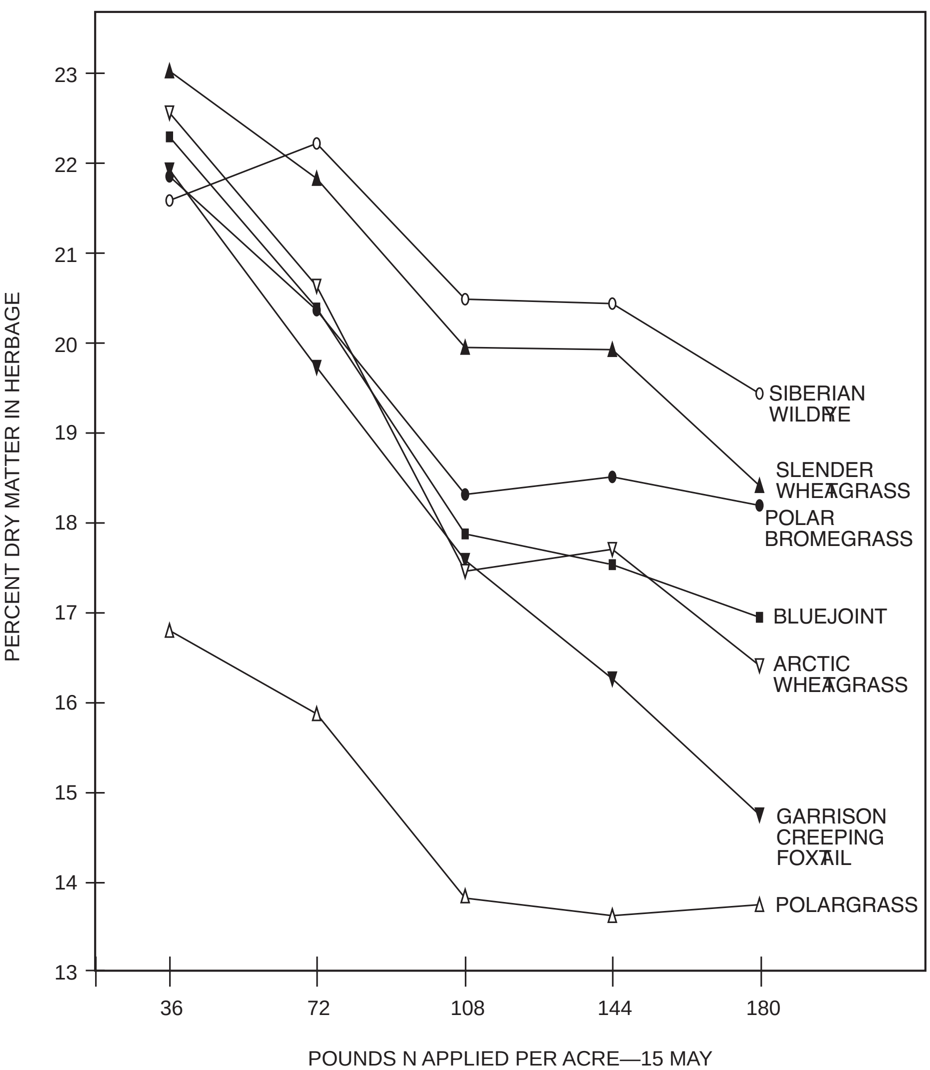


Figure 6. Percent dry matter in herbage of seven grasses at harvest on 29 June as influenced by five rates of N applied 15 May. (Experiment III).

was higher in the first cutting on 29 June than in the second cutting on 18 September (Table 3). Increasing rates of N tended to increase percent IVDMD in the first harvest but had little effect on second-cutting forage. Strangely, the 108 lb/A rate (72 lb/A spring + 36 lb/A summer) had a depressing effect on the mean percent IVDMD for all grasses in both cuttings, but more so in the first; however, depression of the mean value was influenced more by some grasses (Polar, Garrison, Siberian wildrye) than others (slender wheatgrass, polargrass) that showed no depression.

In general, percent IVDMD in the two cultivated grasses, Polar and Garrison, was little changed by increasing rates of N. Similarly, Calder and MacLeod (1968) found no significant differences in percent IVDMD of smooth bromegrass and timothy with four different N rates (0 to 800 lb/A). In contrast, percent IVDMD in most of the native grasses (polargrass, bluejoint, and the two wheatgrasses) increased considerably with increasing N rates. At the lowest rate of N fertility, the native grasses generally were lower in percent IVDMD than the cultivated ones; however, with their marked increase with higher N rates, all grasses were quite similar at the two highest N rates.

In the second cutting, the native grasses tended to be lower in percent IVDMD than the cultivated grasses, with the exception of polargrass and Siberian wildrye which often equalled Polar and Garrison, especially at the higher N rates. Arctic wheatgrass and bluejoint were generally lowest of all grasses in percent IVDMD in the second cutting.

In Exp. II, bluejoint tended to be lowest of all grasses in percent IVDMD in first cuttings; Mitchell (1987) also reported low percent IVDMD for bluejoint compared with several other grass species at this location. In Exp. III of the present study, however, the higher N rates helped to elevate percent IVDMD in bluejoint to levels comparable with the other grasses, though that increase was more evident in the first than in the second cutting (Table 3).

Laughlin *et al.* (1984) in Alaska reported that increasing rates of N and K fertilization (but principally N) significantly decreased the silicon (Si) concentration in bluejoint herbage. Those workers cited the report of Van Soest and Jones (1968) that proposed "an average decline of three units of digestibility for each unit of silica in the dry matter." Although no digestibility determinations were reported for their bluejoint samples, Laughlin *et al.* (1984) conjectured: "Our results indicate that when adequate N and K are applied, the Si concentrations may be reduced, thereby increasing the forage's digestibility."

Results in the present study whereby increasing rates of N application did in fact significantly increase the digestibility (% IVDMD) of bluejoint in both cuttings (Table 3) may relate directly to their hypothesis. Further research should be pursued to better elucidate these relationships; specific fertility recommendations could emerge that would greatly enhance the nutritional value of bluejoint forage.

Digestible dry matter yields: As the term implies, digestible dry matter (DDM) is that portion of the total forage dry-matter yield that is digestible to consuming animals. Figure 7 presents total yields of digestible dry matter for both cuttings for all seven grasses and as influenced by the five different rates of applied N.

Increasing rates of applied N increased digestible dry matter yields up to the 216-lb/A rate, but only two grasses (arctic wheatgrass and Siberian wildrye) showed continued increase at the highest N rate while the other grasses declined somewhat. At the lowest rate of N, the range in DDM yield between lowest and highest grasses was only 0.47 T/A (0.98 to 1.45 T/A); however, at the 216-lb/A N rate, that range had widened considerably to 0.81 T/A (1.64 to 2.45 T/A).

The increase in yields of digestible dry matter with increasing rates of N was due both to increasing yields of total dry matter and to enhanced digestibility (percent IVDMD) of that dry matter as shown in Table 3.

The increasing DDM yields of the grasses compared tended to form into two groups, and each group included both native and cultivated grasses (Fig. 7). The

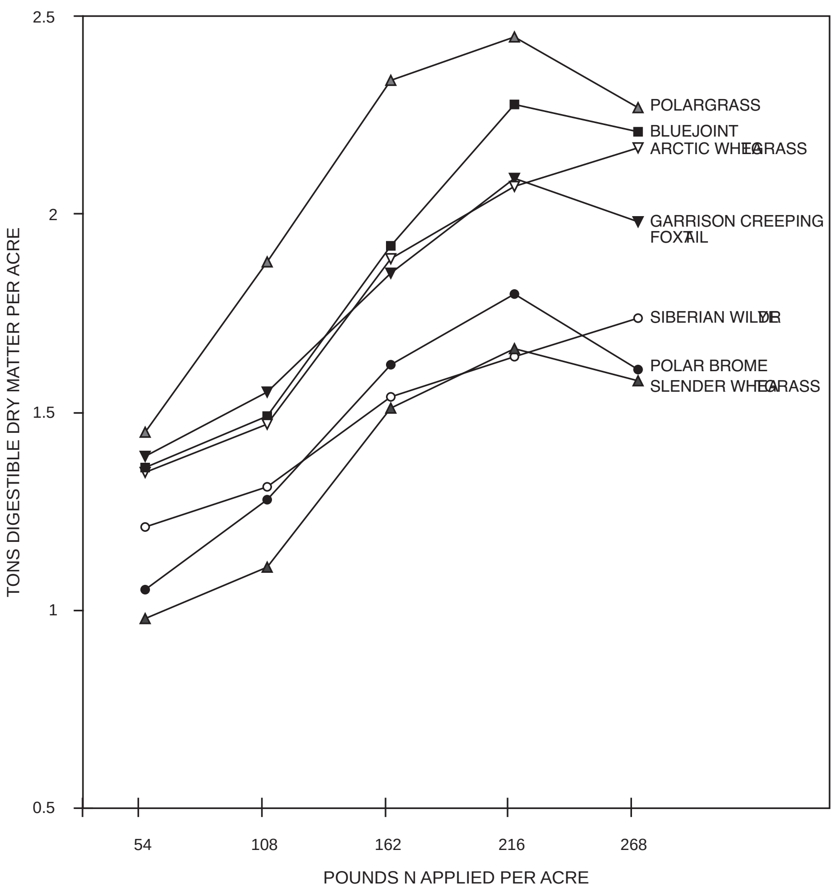


Figure 7. Total yields of digestible dry matter produced in two cuttings by seven grasses and as influenced by five rates of applied N. (Experiment III).

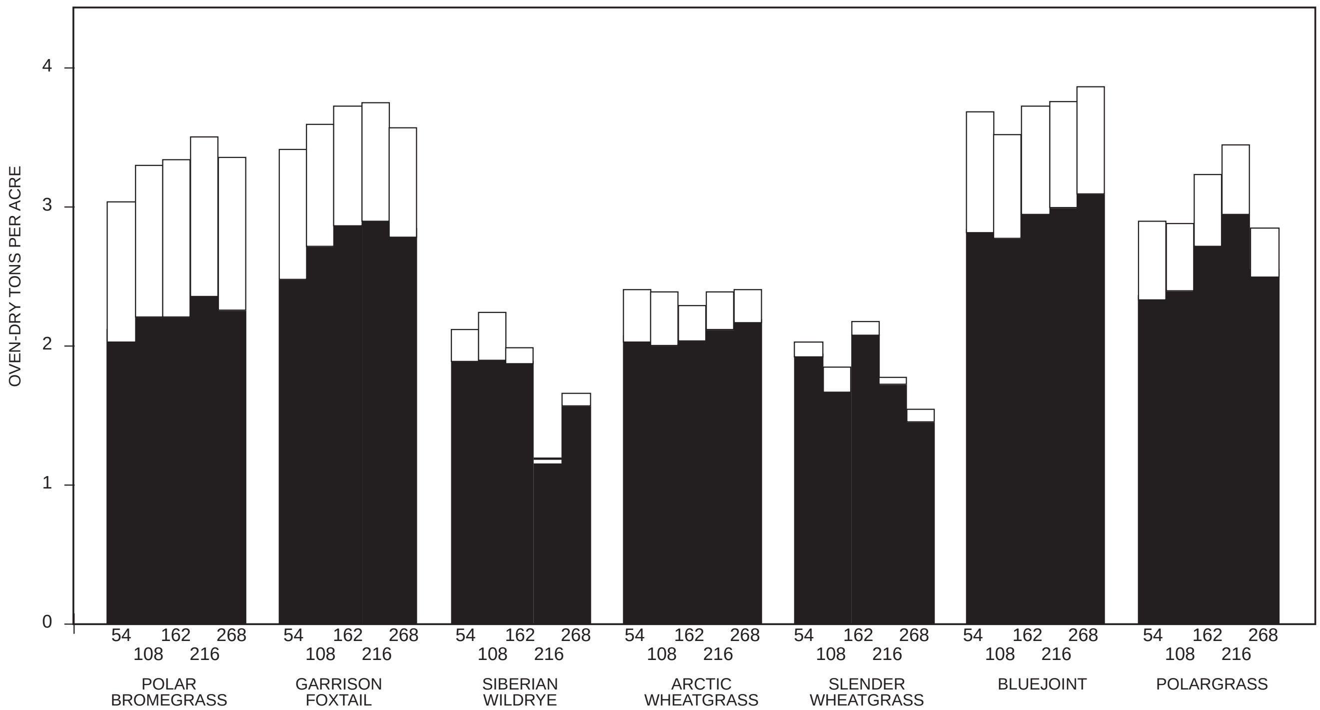


Figure 8. Forage yields in two cuttings in 1973 of two cultivated and five native Alaskan grasses to measure any residual effects of different N rates applied the previous year (1972). Although all grasses were fertilized uniformly in 1973, N rates that had been applied the previous year appear below graph bars. Black portion of each bar represents yield in first cutting harvested 5 July, open portion represents second-cut yield on 5 September.

lower group included Polar bromegrass, Siberian wildrye, and slender wheatgrass, while the higher group included bluejoint, arctic wheatgrass, and Garrison foxtail. Surpassing that higher group, native polargrass was substantially superior to all other grasses at the three middle N rates; however, native bluejoint was also very high in DDM yield at the two highest N rates.

Mitchell (1979) compared different analyses and rates of fertilizer application on bluejoint on the lower Kenai Peninsula and also found that increasing rates of fertilization generally increased forage yields, percent IVDMD of that forage, and thus the yields of digestible dry matter. Those results were obtained on a native stand that earlier had been modified by rotary plowing that leveled the hummocky field surface and incorporated the surface accumulation of organic debris into the mineral soil.

Crude protein: Percent crude protein in all grasses was higher in the first cutting at all N rates than in the second cutting (Table 3). Increasing rates of N application generally increased the percent crude protein (N concentration) in all grasses, a common characteristic noted in other reports (Branton *et al.* 1966; Klebesadel 1965; Krueger and Scholl 1970; Kunelius 1979; Kunelius *et al.* 1976; Laughlin 1953; Laughlin *et al.* 1984; Lutwick and Smith 1979; Smith 1972). In the first cutting, the increase in the mean percent crude protein of all grasses from the lowest to highest N rate was about 90%, while in the second cutting the increase was only about 36%.

In general, Garrison foxtail and polargrass tended to be lowest in percent crude protein in the first-cutting, while arctic wheatgrass often was lowest in the second cutting. Other than those distinctions, no pattern of superiority or inferiority was apparent among grasses nor between the categories of "cultivated" and "native" grasses.

Harvests after conclusion of experimental treatments

Uniform fertilization was applied to plots in 1973 and 1974 and uniform harvests of all grasses were taken twice in 1973 (5 July and 5 Sep.) to ascertain any carryover or residual effects of N rates applied in 1972. Two harvests were planned also for 1974 to gain information on persistence of grasses but abnormal precipitation deficit (see Fig. 1) after a first cutting on 25 June limited regrowth of grasses to such meager amounts that no second cutting was taken.

Some very minor residual effects of 1972 N rates were apparent in 1973 in first cuttings of Polar brome, Garrison foxtail, bluejoint, and polargrass (Fig. 8). Those grasses were the highest yielding in 1973, bluejoint higher than the other three. The other three native grasses, Siberian wildrye and the two wheatgrasses, were considerably lower yielding and Siberian wildrye and slender wheatgrass tended to be lower yielding where highest rates of N had been applied during the prior year. There was no evidence of residual effect of different N rates applied in 1972 in the second cutting of 1973.

First-cutting yields on 25 June 1974 averaged over 2 T/A and were quite similar for all grasses, indicating that all grasses again survived the winter well and all

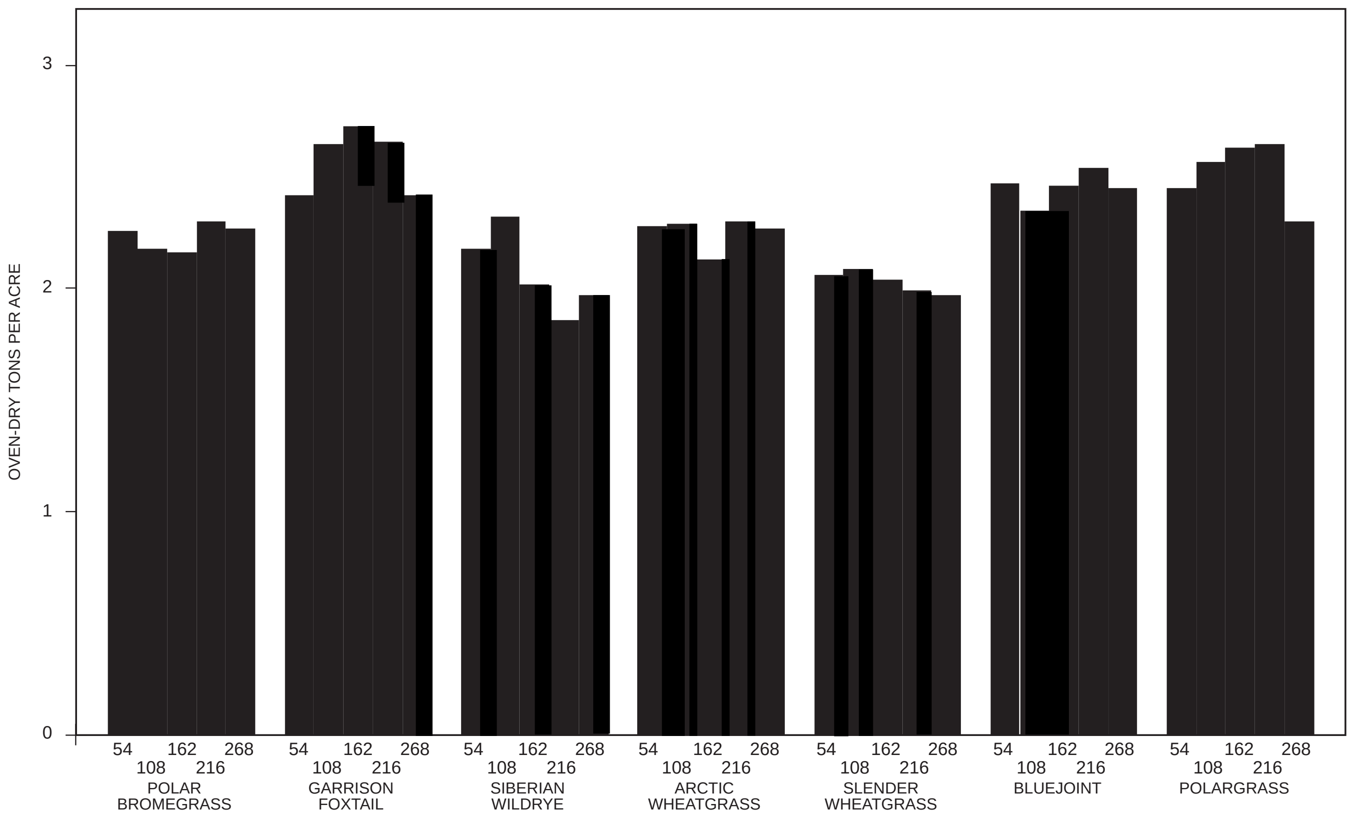


Figure 9. Forage yields harvested 25 June 1974 of two cultivated and five native Alaskan grasses to measure persistence of grasses in the sixth year of growth; a planned second harvest was not taken as abnormally low precipitation (Fig. 1) severely restricted regrowth of all grasses. Although all grasses were fertilized uniformly in 1973 and 1974, N rates that had been applied in 1972 appear below graph bars to permit identification of those treatments and to conform to Figure 8 for continued comparisons.

showed good persistence (Fig. 9). There was virtually no evidence of residual effects on yields in 1974 from the different N rates applied in 1972; this result agrees with a report by Lutwick and Smith (1979) who found that carry-over effects of N soon disappeared. Polargrass yield in 1974, as in 1973, showed continuing evidence of slight depression where the highest rate of N had been applied in 1972.

The good yields of Siberian wildrye in that final harvest, indicating good stand persistence and productivity in the sixth year of growth since planting in spring of 1969, was somewhat surprising as workers in other areas have described Siberian wildrye as a "short-lived" grass (see review of other reports, Klebesadel 1969b). The good persistence of Siberian wildrye over six years in this study, contrasted with the poor persistence of two strains reported by Lawrence (1978) in southwestern Saskatchewan, may be due to differences in moisture and evapotranspiration; the semi-arid and warmer growing seasons at the Canadian location may be more detrimental to good persistence for this grass.

Rationalizing the Myth: "Bluejoint Won't Tolerate Harvesting Every Year"

Cumulative experiences of many Alaska farmers and ranchers, documented in some reports (Aamodt and Savage 1949; Irwin 1945; Klebesadel and Laughlin 1964; Laughlin *et al.* 1984; Mitchell 1979; Mitchell *et al.* 1983), are in general agreement that native stands of bluejoint decline in vigor and yield when harvested annually.

This led Aamodt and Savage (1949) to interpret that behavior as an intrinsic shortcoming of the grass for forage use; they stated (p. 115): "The inability of bluetop (bluejoint) and other native grasses of Alaska to withstand close and frequent use is undoubtedly the result of the conditions under which they have evolved. These plants, unlike those of the Great Plains, have had no opportunity to develop resistance through generations of use by buffalo or domestic livestock."

Furthermore, native stands of bluejoint generally have shown very meager responses to applied fertilizers. Those experiences contrast with the good responses of bluejoint to levels of applied fertilizer apparent in these experiments and especially in Exp. III.

The results of the present investigation and other recent studies with bluejoint, both in modified native stands and when seeded on cropland soils, have effectively disproved the contention that bluejoint responds poorly to fertilizers and persists poorly if harvested twice or even once per year (Klebesadel 1965; Laughlin 1969; Mitchell 1979, 1982).

A rationalization of all of these conflicting perceptions of bluejoint responses to harvesting and fertilizers logically lies in the dissimilarities of conditions under which bluejoint has been evaluated. Bluejoint generally has been evaluated under three major types of situations:

(a) The disappointing farmer/ rancher experiences with bluejoint were with largely unmodified native stands characterized by a considerable layer on the soil surface of undecomposed organic debris that had accumulated over years by annual die-back of the grass growth produced each year. Due to the high carbon/nitrogen ratio within that surface accumulation of straw-like debris, microorganisms that decompose the debris quickly appropriate available nutrients (especially N). Thus little of the applied fertilizer nutrients pass through that surface organic mat to reach and benefit the living grass. Grass response to applied fertilizers is therefore minimal to nil and the essentially unfertilized grass understandably tolerated harvests poorly.

(b) Forage production has been studied in modified native stands wherein the accumulated organic debris was removed by blading (Klebesadel 1965; Laughlin 1969), incorporated with a rotary plow (Mitchell 1979), or leveled and reduced by a flail chopper (Laughlin *et al.* 1984). Under those conditions, bluejoint tolerated two harvests per year and responded well to fertilizers.

(c) Bluejoint has been seeded in mineral soil and compared with other grasses at high rates of applied fertilizers as in the present study and others (Mitchell 1982, 1986, 1987); under those conditions, bluejoint has produced and persisted well.

Therefore, the historic poor performance of bluejoint under conditions cited above in (a) (poor persistence and negligible response to fertilizers) is seen to be due to the unique characteristics and conditions of the native stands rather than inherent deficiencies in the grass itself.

CONCLUSIONS

The results of the three experiments lead to new information and conclusions in several categories.

Winterhardiness

Of the nine different grasses compared, Engmo timothy and the non-cultivar commercial lot of meadow foxtail were the least winterhardy. Inasmuch as Engmo ranks as one of the most winterhardy among many North American and European strains of timothy compared here (Klebesadel and Helm 1986), timothy as a species must be considered less winterhardy in this area than all other species compared except meadow foxtail. Both Engmo and meadow foxtail showed a good capability to recover stand health, vigor, and productivity after severe winter injury in Exp. I. However, the recovery observed was possible only because winter injury was not more extensive. When Engmo sustained greater injury near the end of Exp. II, recovery was not possible.

The severe winter of 1970-71 revealed Polar bromegrass and Garrison creeping foxtail to be slightly less winterhardy than the five native Alaskan grasses. No winter injury was apparent in any of the native grasses compared.

Forage Yields

None of the grasses compared was consistently superior nor inferior to the others in forage yield. Polar bromegrass and Siberian wildrye tended to be the highest yielders (when cut twice) in Exp. I; bromegrass and timothy were generally highest with the different harvest schedules in Exp. II, but slender wheatgrass was highest in the first cutting of the following-year evaluation harvest.

In Experiment III, Garrison foxtail, arctic wheatgrass, bluejoint, and polargrass tended to be highest yielders while, in the first year after termination of Exp. III, Polar brome, Garrison foxtail, bluejoint, and polargrass all about equally surpassed Siberian wildrye and the two wheatgrasses. And in the sixth year of the stands previously used for Exps. II and III, Garrison foxtail and the two native members of the Agrostideae grass tribe (bluejoint and polargrass) tended to slightly outyield the other grasses in the single harvest taken that year.

Seasonal Distribution of Forage Yield

The native Alaskan grasses often equalled or surpassed the cultivated grasses in first-cut yields; this was especially true when winter injury depressed yields of the cultivated grasses.

However, the cultivated grasses, Polar brome, Engmo timothy, meadow foxtail, and Garrison creeping foxtail tended to produce more forage in the second of two and the third of three cuttings than did the native Alaskan grasses. Native slender wheatgrass generally was the lowest yielder of all grasses in the final harvests regardless of frequency of harvest (2, 3, or 4 cuts/year).

Engmo timothy, when not severely winter-injured, often was the highest yielder in the second of two cuttings per year if the first cutting was taken 23 to 28 June or earlier. However, because Polar usually surpassed Engmo in first-cutting yield, total-year yields of the two usually did not differ significantly.

Tolerance of Grasses to Harvest Schedules and Frequencies

One of the more conspicuous disparities noted among grasses was a dissimilar tolerance of Polar bromegrass and Engmo timothy to the various harvest frequencies. Polar responded best to two harvests per year and was progressively disfavored by more frequent (3 or 4) harvests per year. In contrast, subsequent winter survival of Engmo was poorest with two harvests per year and was favored by progressively more frequent harvests. From the viewpoint of on-farm utilization, Engmo therefore is better suited for more frequent harvest as occurs with green-chop feeding; bromegrass, in contrast, is ill-suited to that utilization avenue and ideally should be harvested twice per year.

A third response noted was a better tolerance to two or four harvests per year than to three cuttings in meadow foxtail, Siberian wildrye, and arctic and slender wheatgrasses. Further work is needed to derive a better understanding of the cause(s) of that seemingly unusual response pattern.

The cultivated grasses Polar brome and Garrison creeping foxtail were much more predisposed by three and four cuttings per year to injury during a subsequent severe winter than were the four native grasses compared.

Forage Quality

Digestibility of forage (percent IVDMD) was higher for all grasses when they were cut frequently and therefore at more leafy, immature stages of growth; however, the more frequent harvests resulted in lower dry-matter yields. Growers therefore have the option to choose some compromise between forage quality and yield as their feeding requirements dictate.

With two cuts per year on three different schedules (different first-cutting dates, same final-cut date) mean percent digestibility was near identical with all three; this occurred because as digestibility decreased with progressively later first cuttings, shorter periods of regrowth prior to the final cutting resulted in progressively higher percents digestibility in those second cuttings. This information also provides growers with informed choices in harvest scheduling.

Native bluejoint has been found in other investigations, and at low N rates in the present study, to be low in digestibility. The present results, however, showed that the highest levels of applied N elevated percent IVDMD in bluejoint herbage, especially in the larger first cutting, to levels comparable with the other grasses.

Increasingly higher rates of applied N resulted generally in (a) progressively higher percentages of crude protein in both the first and the second cuttings, (b) enhanced digestibility of forage, and (c) increased yields of both total forage and digestible dry matter. The economic implications of those cost-and-return options go beyond the scope of this report and must be evaluated for specific operations by growers themselves.

Persistence of Stands

Except for the loss of Engmo timothy to winterkill between Exps. II and III, all grasses persisted well with continued high forage production through the sixth year of growth in the follow-up harvests taken after termination of Exp. III.

The continued good persistence and productivity of Siberian wildrye and slender wheatgrass into the sixth year of their stands was surprising in view of the generally accepted view of those two as relatively short-lived species.

Bluejoint persisted well with good stands and high forage yields into the sixth year of growth, despite having been harvested once in the seeding year and from two to four times per year thereafter. These results and other recent studies confirm that the poor persistence and progressively lower yields obtained when this grass is harvested as infrequently as once per year in native stands is a result of conditions characteristic of those native stands rather than due to inherent shortcomings in the species itself.

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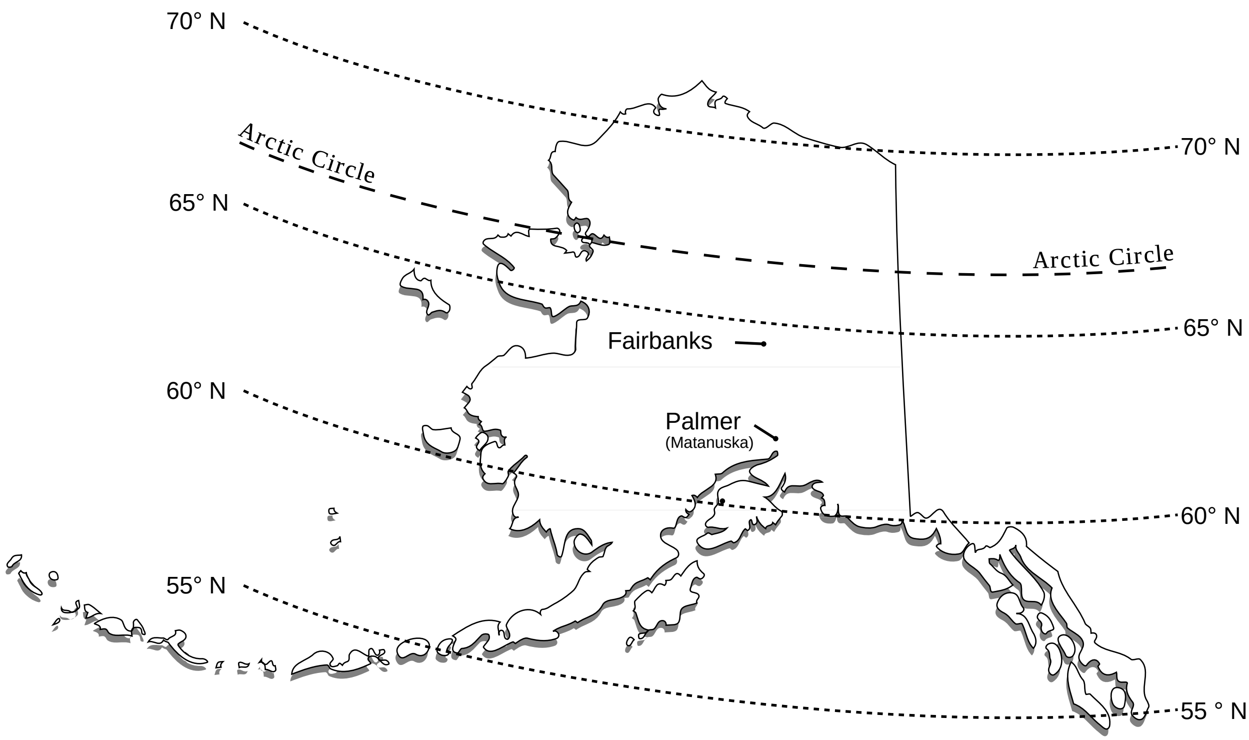

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